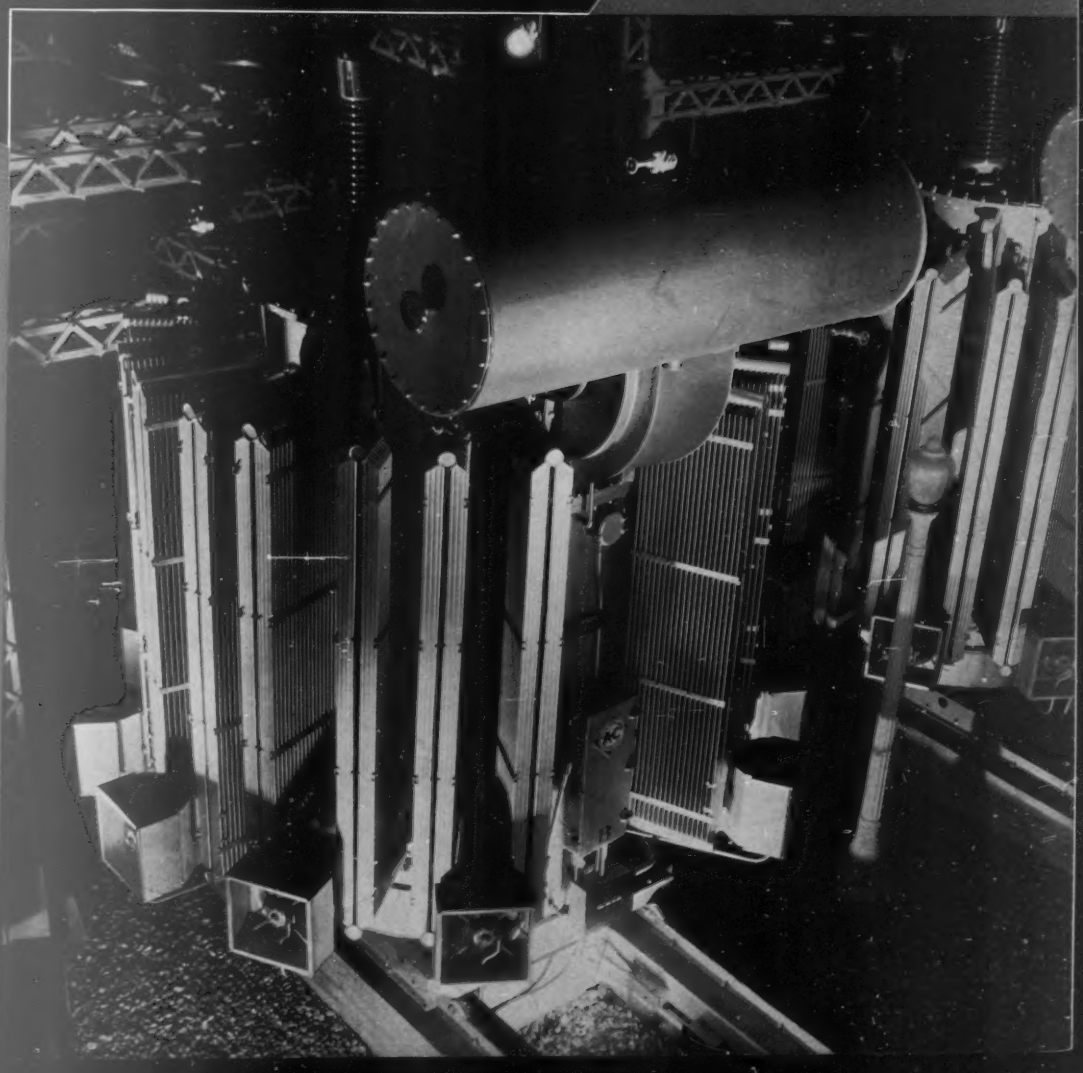
ALLIS-CHALMERS

# ELECTRICAL REVIEW

September • 1937



# RUPTORS

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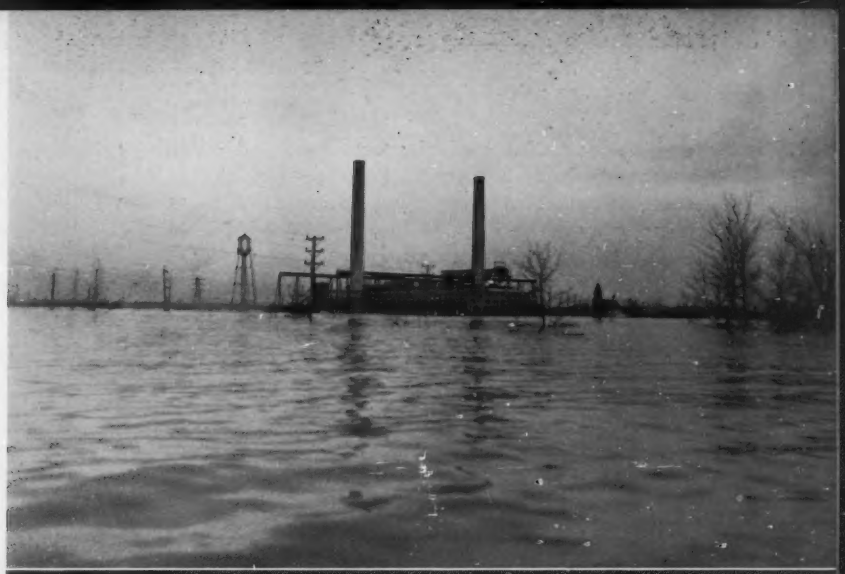


# THE RECLAMATION OF A FLOODED POWER STATION

• J. D. Roberts, Chief Engineer
CENTRAL ILLINOIS PUBLIC SERVICE CO.

There are few sights that can present a more discouraging task than the appearance of a large power station after a flood — oil, mud, debris of all kinds throughout the plant, covering as well as penetrating all parts of the plant, buildings, and equipment.

The Muddy Power Station of the Central Illinois Public Service Company located near Harrisburg, Illinois, on the middle fork of the Saline River, twenty-five miles from the Ohio River, was completely submerged for 14 days.

This power station contains, in the main plant buildings, 25,000 kw in steam turbo-generators in four units, and nine boilers equipped with underfeed forced draft stokers. All auxiliaries are motor driven, and each of the four generators and their complement of boilers and auxiliaries are separate units. The switchhouse is a separate building connected to the main building by a system of underground cables and ducts, and in it are located the main station 2300 volt busses and switchgear; connected to this switchhouse by underground cables and ducts are two outdoor switchyards, one of 33 kv supplying four transmission lines and one of 66 kv supplying five circuits of transmission lines. In the switchhouse are six 2000 kw 2300/33000 volt transformers, and in the 66 kv yard are three 5000 kw and three 2000 kw 2300/66000 volt transformers. In the switchyards are high voltage oil circuit breakers, current and potential transformers, lightning arresters and control equipment for each line supplied, and bus tie oil circuit breakers for main and transfer busses.

All of the station auxiliary power transformers and the 440 volt switchgear for station power supply are in the main station building basement — all remote controlled from individual stations throughout the plant buildings; also in this main building is a 500 kw geared steam turbo-generator for emergency plant service. All the turbo-generator units have direct-connected exciters; three of the main units are 5000 kw, 3600 rpm, and one is 10,000 kw at 1800 rpm.

Involved in the reclamation of the station was the drying and repairing of the main units, all switchgear, transformers of all classes, switchboards and instruments, and 71 motors varying in size from 400 hp to the small governor speed control motors, cables of all types including lead sheath, paper and varnished cambric, and rubber insulation.

The entire main building, switchhouse, machine shop, office and storeroom, and water treating plant buildings were flooded to a depth of eight to nine feet above their main floor levels. The outdoor switch and transformer yards were flooded to varying depths of eight to ten feet. During much of the time freezing temperature prevailed.

## • Preliminary work

As the flood water receded to levels that permitted entrance to the main floor levels of the buildings, water service was established, and with lines of hose, rubber-faced scrapers, brooms, etc., the building wall, floors and such equipment as was located on these levels were washed down,

and the accumulation of oil, grease, mud and debris was washed out of the main floor opening into the station yard. Temporary pumps were installed to unwater the basements, and as the water levels in the parts of the buildings permitted, washing down and removal of mud and debris proceeded. This part of the work was done more thoroughly, for as soon as the basements were unwatered, steam was raised on one of the boilers and by use of live steam into feeder water heaters, hot water, available through service lines, permitted faster cleaning and grease removal.

Temporary crane service was established by using a motor-generator set located in a coal mine nearby. The trolley and rails of an idle traction line served to transmit the power. Dismantling of the main generating units and the most urgently needed auxiliaries then proceeded.

## • Cleaning of electrical and mechanical equipment

When the main generators were opened and the rotors removed, it was found that deposits of silt mixed with oil and grease covered all parts of the windings, laminations, and machine frames, and had entered the turbine bearings, oil piping, oil reservoirs, governors and other internal parts.

To clean mechanical parts where electrical windings were not involved, a compressed air atomizing spray using kerosene was very effective; for large parts, such as frames, bearing caps, generator end frames, a solution of three-fourths ounce of Okite powder to one gallon of water used hot with the air spray did a good job and did not remove paint or varnish. It was necessary, however, after using this solution, to wash the equipment thoroughly with hot water in order to remove all alkali; otherwise later painting and varnishing could not have been done successfully.

This solution was used also for cleaning the generator stators, motor stators, and rotors. For smaller motors, instrument transformers, controllers, and operating gear of oil circuit breakers, where the work could be done outdoors in open air, good results were obtained with high test gasoline (not compounded with Ethyl). For the internal parts of oil circuit breakers, bushings, barriers and similar parts, carbon tetrachloride was used successfully; this material was used also in cleaning bus compartments and insulators. Care was taken that all workmen using it wore gas masks.

For direct-current exciters Okite solution was used to remove mud and grease, and the final

**Right, from Top to Bottom — Turbine Room. Boiler Room (both pictures taken when water was one foot below maximum). Sixty-six kv Transmission Line. Partial View of 33 and 66 kv Yards. Note submerged Potential Transformers.**

cleaning was done with high test gasoline. The field coils and assembly of the direct-current machines were also cleaned with Okite solution and hot water; and in cases where heavy grease deposits were involved, high test gasoline.

Due to the number of units and facilities controlled, the switchboard of this station is extensive and complicated. It was first thoroughly washed down with the air spray and Okite solution, then cleaned with tetrachloride; all instruments were removed and sent to our central meter repair shop for reconditioning.

All steel conduit systems for station light and power circuits were opened at all low points, such as junction boxes, condulets, or by drilling small holes through the conduits at points where they would drain. They were blown out with tetrachloride and compressed air and then dried with compressed air. This method was very successful in that only a small amount of wire and cable had to be replaced.

## • Drying out equipment

We built a large steam heated drying oven 16' x 14' x 12' with a large door in one end and with a top that could be lifted with the turbine room crane. Steam coils of one inch pipe welded to three inch headers located on the floor and side wall furnished the heat; these were supplied from the 250 pound superheated steam system. A series of openings at the floor level along the sides admitted air through and upward from the lower steam coils. A stack or flue located in the cover provided draft through the oven. This oven was constructed on a 2" x 4" frame covered inside and outside with one-half inch cellulose composition board. Each bank of steam coils was drained through a three-quarter inch steam trap. The temperature was controlled by varying the steam supply and air flow. On the floor 8" x 16" timbers were placed between the coil sections, and lengthwise across the oven. Timbers were also placed to support the equipment that was placed in the oven for drying. All equipment except the main generator stators and rotors was dried in this oven successfully. Temperatures up to 123° C. were easily obtained and controlled.

Our experience taught us that there were no definite standards of time or temperature to be applied in drying out equipment. This we felt to be true because the time of submergence, the head of water to which the equipment had been subjected, the age of the insulation, and the materials of which it was constructed were the factors that determined the drying out time and the method to be used.

The stators of the main units were initially dried by regrouping the coils at the terminal leads and using direct current from one of the motor-driven emergency exciters. This unit was separately excited from a small motor-generator set in order to control the current supplied to the stator windings. Using a 50 kw set in this way, we obtained ample current for drying the stator of the 10,000 kw unit and one of the 5000 kw units.

Drying was started with very low current values, allowing 48 to 50 hours for temperatures to rise to 50° C., and at no time to exceed 70° C. After 240 hours, insulation resistance readings began to show a rising trend, and in 300 to 350 hours stable or constant reading at drying temperature were obtained. We covered the stators with canvas and closed the air ducts. When the rotors were installed, the stators were reconnected and short circuited; and with the turbine at full speed, sufficient field was supplied to get about one-third normal stator current in the coils. Temperatures were controlled to 50° to 60° C. by closing the air inlet through the air washers to the generator, thus allowing air to circulate through the stator at high velocity and to carry off any moisture driven from the coils.

Painting of the coils was not done until final drying was completed as indicated by resistance measurement of insulation, when obtained at drying temperatures. We followed this procedure since initial drying by heating the coils with direct current drives the moisture from the inner part of the coils out to the exposed portions; and because of the type of insulation and the taping of the exposed ends, we felt certain that later drying under forced air circulation at pressure from the rotor fans would drive out the moisture from the coil ends. Our experience has since confirmed this.

As far as drying the generator rotors is concerned, we do not believe that it can be done safely except in a vacuum drying oven under full control of temperature and gradual increase of vacuum from the start of the drying operation. For this reason all rotors were returned to the manufacturer. Balancing is necessary in all cases after drying, for coil blocking material will undoubtedly swell when wet, and after drying may shift or require replacement. This class of work can best be done in the builders' shops, and particularly is this true if the end caps must be removed from the rotors.

We replaced all stator coil wedges and cell covering fiber strips, coil roping, spacing and fiber shims; the materials, such as fiber, fish paper, and similar material, swelled and under preliminary drying shrunk so much that they could be removed by hand pressure. Incidentally, this applied to all motor slot sticks in either rotors or stators, cell covers, and slot insulation.

One of the oldest generator stators we did not attempt to dry out. This winding had been in service twenty-one years and contained a large amount of varnished cloth in its insulation.

Direct current field coils were readily dried out by use of combined current heating and oven drying. Direct current armatures were no problem, except for the commutators. These were successfully dried by removing the V rings or clamping segments and placing in the oven. It is well to wrap the commutator segments tightly with binding wire before disassembly. After replacing the V rings or clamping segments the commutators were trued up in a lathe.

We replaced all slot wedges and fiber strips and rebanded the armatures after drying, since the shrinkage of channel insulation caused the coils to become loose. This was true also in the case of all wound rotors of induction motors. Fiber collars or bushings of slip rings shrunk to such an extent that slip rings could not be trued until replaced. We made these parts from fiber rod and heavy sheet stock. A squaring shear of the type used for cutting sheet fiber insulation saved considerable time in cutting slot wedges and cell insulation for motor repairs.

Power transformers and high voltage current or potential transformers were successfully dried in the oven at a temperature of 85° C. These required from 10 to 20 days depending on the size and type of coil winding, but in all cases they were dried until constant insulation readings were obtained at the drying temperature. Insulation readings were always taken between high and low voltage coils and high and low coils to core. As quickly as possible after removing the hot coil and core assembly from the oven, we placed them in their tanks, which had been cleaned and filled with new oil that had been filtered and tested so that in cooling, oil would penetrate rapidly into the coils and core.

Small instrument transformers of the air cooled or dry type could not be in all cases dried out. Those of the older types built prior to 1924 were discarded.

We do not believe that in any practical or economical way can lead sheathed, varnished, cambric insulated cable, into which water has penetrated for any distance, be dried out or reclaimed. The majority of the cables of this type in use terminated in the basements of the main building and the switchhouse. They were subjected to approximately 15 pounds per square inch water pressure, and although they terminated in compound filled potheads, water did enter these cables. In some cases water entered the cables through the potheads, apparently through shrinkage voids between the pothead filling compound, the cables, and the pothead shell. In other cases minute sections of deteriorated sheath permitted water under a pressure of approximately 15 pounds per square inch to be forced through a porous spot in the lead sheath of the cable. In no instance were we successful in reclaiming any of the varnished cambric lead sheath cable, either of the single or multiple conductor type.

The loss of paper insulated lead sheath cables was very slight; these cables apparently swelled as water entered the ends of the cable at the pothead. The paper insulation in some instances swelled to such an extent that it virtually sealed the end of the cable. We were successful in removing the potheads on many of these cables, splitting the insulation along the cable from one to three feet, laying the sheath back, and reinsulating the leads. The filler core was removed and replaced with dry filler material and the sheath was closed and wiped. The potheads were refilled with compound and the cables were reinstalled. In other cases where sufficient length of cable was available after leaving the cable ducts, we cut the cable off, spliced a new piece on, wiped the joint in the lead sheath, and extended the cable on into the pothead.

Where close connections to the switchgear were involved, we merely cut off the pothead, wiped in a new sleeve and trifurcated a single three-conductor lead cable joint from this sleeve to the switchgear connection. We found it quite desirable, in drying out the generator stators by short circuit, to install short circuit connections at ends of the cable runs so that all cables involved in the series of electrical connections would be heated up at the same time the generator stators were being dried out. In such cases the potheads were not installed on the cables until after the drying-out operations had been completed.

There is a rather large amount of connecting cables between generators and combining busses in the basement of the main plant building that consist of jute core stranded copper, with varnished cambric insulation, and braided protective sheath over the insulation. Since these cables terminate in the discharge air duct of the generators, considerable hot air, forced out through the duct, runs to the open ends where the cables terminate. These cables were successfully dried out at satisfactory insulation readings under short circuit conditions in conjunction with the hot air forced through the ducts. The cables that have not been replaced all operate at 2300 volts, and we believe that failures in these cables will not take place at a later date due to this low operating voltage.

All closing coils and trip coils of circuit breakers were replaced, as it was practically impossible to get the moisture out of them even by vacuum drying, and because immediate use of the circuit

breakers was necessary. It was cheaper to replace the coils than to experiment with attempts to dry them.

All lightning arresters of the oxide film type which were submerged were completely discarded. We could not successfully reclaim the oxide film cells by drying and be assured of proper operating characteristics of the arrester. The oxide material within the cells caked and packed in various forms and came in contact with the metal plates of the cells. The amount of apparatus to be protected did not justify experimenting with these lightning arresters.

## • Repairs to mechanical equipment

Temperatures below freezing existed for quite some period of time while the station was flooded. Water and steam piping could not be successfully drained, for much of it was frozen and had burst. Acetylene and arc welding, with few exceptions, were the means used in repairing such damage.

Boiler settings in practically all cases required replacement of refractory linings and portions of the boiler setting walls. The settings of six of the older boilers were insulated between the refractory lining and the setting wall with insulating brick. This brick disintegrated under the action of water, and as drying out of the settings proceeded, the disintegrated material swelled to a marked extent, bulging the setting walls and making necessary their replacement.

Underfeed stokers, due to the large amount of silt that settled in the furnaces, were cleaned, washed with kerosene, and the moving parts were oiled with oil reclaimed from transformers, circuit breakers, etc.

All gear boxes and variable speed gear drives of these stokers had to be completely disassembled, washed with kerosene, reassembled, and realigned. All rawhide pinions used in the stoker drives had to be discarded. This material swelled and was so distorted it could not be used.

Boiler feed pumps and service pumps in the boiler room and main floor level, like the main steam turbines, were completely dismantled, cleaned, reassembled, and adjusted before they were placed in service.

Practically all gauges and plant instruments were salvaged and repaired on the job.

It was found that turbine and insulating oil freed from various parts of equipment floated on the surface of the water and seeped into the clocks of recording instruments. By using a solution of carbon tetrachloride followed by a light mineral solvent and lubrication of the clock mechanisms with standard oils for this purpose, it was possible to put them back into service without dismantling them.

Throughout the entire power station, high pressure steam lines developed serious leaks at flanges and points of connection when again subjected to steam pressure. Almost all gaskets of fibrous material or composition metal had to be replaced.

As a rule, there was no successful way of placing the mechanical equipment in service other than to have it completely dismantled, cleaned, and reassembled.

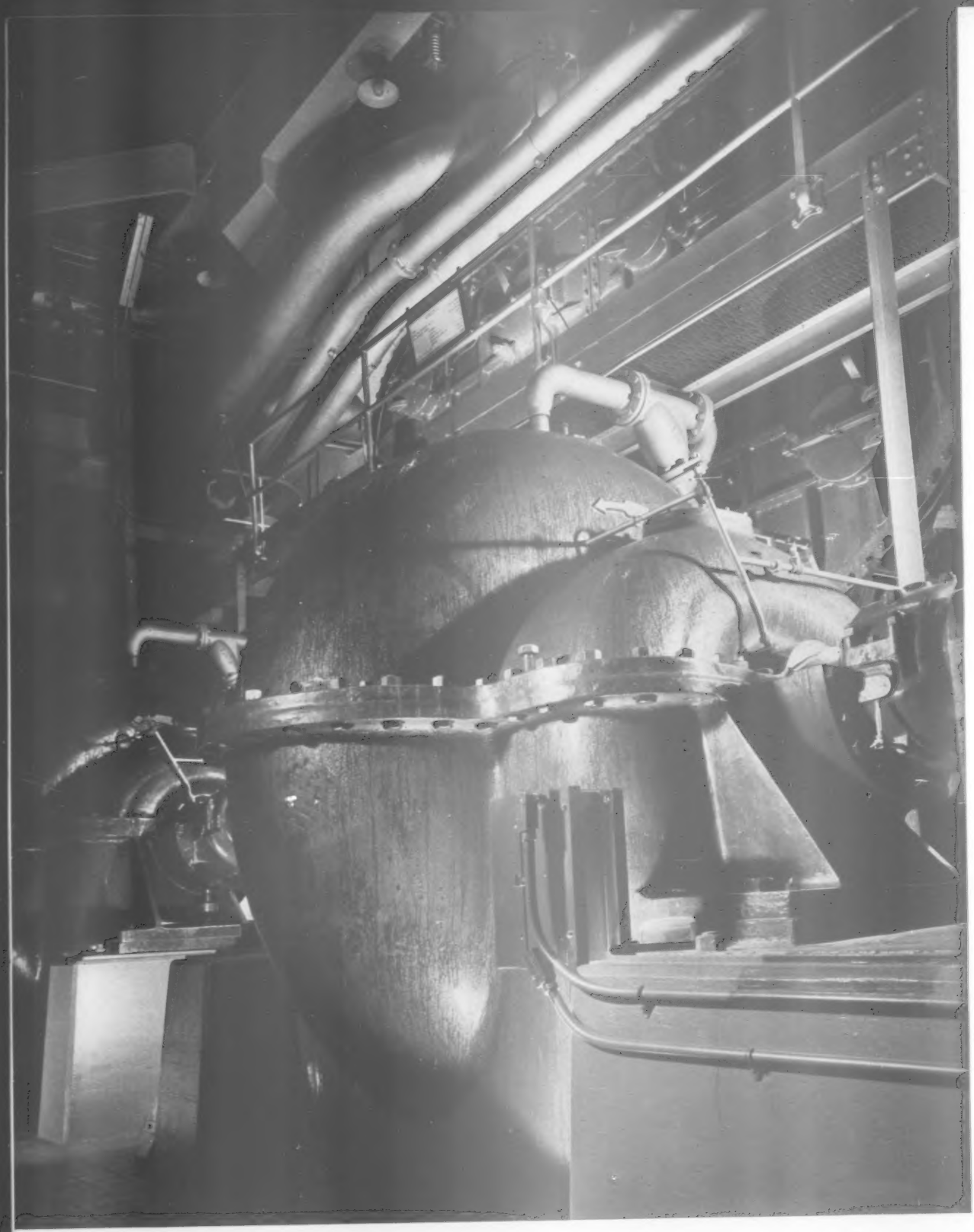
The damage to buildings was of little consequence. Around the north side of the boiler room portion of the main building, at an elevation of about four feet above ground level, there are nine air intakes — one for each of the forced draft fans. On the south side of the building, turbine room section, there are four large air intakes to the turbine air washers.

We were successful in keeping the water from the main building until it was about four feet higher than the turbine room floors. The main building is of pilaster and panel type construction. The nine inch wall between the pilasters in the older portions of the building are laid up in lime and sand mortar. These walls would not stand any further water pressure on the outside. The large number of openings — windows, doors, air intakes, etc. — made it practically impossible to employ bulkhead construction successfully. Even if this had been possible, the inherent weakness in the construction of the building walls would have caused far greater consequential damage than the cost of reclamation.

The main 2300 volt bus is located partly in the basement and second floor of the switchhouse building. The numerous conduit duct runs between the two buildings developed many serious leaks, which were practically impossible to seal off when water pressures reached ten to 12 feet above the duct levels. Again it was realized that the water pressure on the basement floors underneath the concrete slabs was reaching critical pressures. Here again in order to save further consequential and excessive damage, flooding the building was necessary. Beyond requiring painting the building walls in certain places, repairing of duct systems and points where these pass through the station foundation walls, and the final painting of the building yet to be done, there was little direct damage to the building.

We estimate that the rehabilitation costs covering the entire work done at this station contingent directly to flood conditions is approximately $6.00 per kw.

There is a large amount of work in the rehabilitation of this station that is not directly attributable to flood damage, but as a result of the effects on apparatus and equipment, due to the long submergence of the station, a considerable amount of direct maintenance work of necessity had to be done while the apparatus was disassembled during the rehabilitation work.



## CONDENSER AND CIRCULATING PUMPS

# TREND OF DEVELOPMENT IN AMERICAN PATENT LAW*

• John A. Dienner
PATENT ATTORNEY . . . CHICAGO, ILLINOIS

I do not expect to discuss the laws of foreign countries except as they bear upon the general development of patent law as a whole or the development of the patent law of the United States. Naturally, we are most interested in the development of the patent law here in the United States.

All countries laying claim to an advanced state of civilization have established systems of granting patents for inventions. In broad outline, they are the same, namely, they are granted by the state or government, they are based upon a new invention, and they grant the patentee the right for a limited time to exclude others from the use of the invention. Since we are particularly interested in the philosophy of the United States system, it seems probable that in analyzing the nature of the United States patent right we can learn much about the character of patents in other countries and the probable trend of the development of the law of patents as a whole.

## • Patents are peculiar

In the general domain of human activity and interests, a patent is a peculiar thing. It is like nothing else in the law, just as its subject matter is like nothing previously known in the useful arts. While all countries grant patents upon the same general conditions, it appears that there are different concepts as to the nature or character of the corresponding patent. To say that they are artificial monopolies created by law gives no inkling of their real character or their relation to men and to things.

## • System of granting patents

The system of granting and enforcing patents as a procedural matter varies in different countries. For example, the leading systems differ in essential features as follows:

United States

1. Examination for novelty
2. Grant of patent to first inventor only
3. Permissible two-year period of use before filing application for patent
4. Patents are not taxed

Great Britain

1. Limited examination for novelty
2. Provisional (tentative) specification
3. Provision for opposition to patent grant
4. Patent dates from date of application
5. Patents are taxed annually to maintain them in force

France

1. Registration only (no examination for novelty)
2. No specific claims to define invention
3. Patent dates from date of application
4. Patents are taxed annually to maintain them in force
5. Patent infringement punishable by criminal as well as civil action

Germany

1. Examination for novelty
2. Provision for opposition to patent grant
3. Patent dates from date of application
4. A highly specialized form of claim
5. Patents are taxed annually to maintain them in force
6. Patent infringement punishable by criminal as well as civil action

While these procedural matters do not control the philosophy of the patent right, they do indicate the attitude of the respective countries toward different phases of the patent grant. In order to determine the nature of a patent right, it may be well to review the historical facts which brought about the granting of patents.

## • Need of patents

It is easy to see good reasons for the granting of patents, and not so difficult to understand how they came about.

At the dawn of man's development he began to use tools. They were his property. If he made an axe it was his only so long as he retained actual possession of it. If he left it lying where someone else could get it, he had to do one of two things: either regain possession of it, that is, take it by force or otherwise, or make himself another axe.

* Résumé of speech delivered February 16, 1937, before the Patent Law Association of Milwaukee. Printed by permission of the author. (Abstracted by H. S. Silver and L. Teplow.)

In all forms of primitive society, possession or physical control of a thing was the only way of owning property. This means that the strong man could take from the weaker. The common conscience recognized this as wrong. So the common conscience organized an effective sentiment against such taking possession or ownership, and devised the ingenious theory of *"title."*

Now *"title"* may be defined, loosely, as the relation of a man to a thing by virtue of which he cannot be deprived of the thing except either by his voluntary act or by operation of law. If a man has title to a thing he came by it lawfully.

Not only did the conscience of primitive man recognize the necessity for preserving proper ownership, but prescribed punishment for the wrongful taker, that is, the robber or thief.

But when the first axe was invented there was no law to keep any one else from making a Chinese copy of that axe for himself. In the early stages of man's industry no great need was felt for restraining the second man from copying the ideas of the first. But as industry became more highly organized, and as John Doe went into the axe business and depended upon it for livelihood, if he invented an improvement in axes, he naturally wanted that improvement for himself. But how could he keep the improvement if he sold an axe which contained the improvement? For as soon as someone bought the improved axe, containing the novel idea, the purchaser could copy it. So could a third person, a fourth, or a fifth. Thus the inventor would, in the very use of his improvement, throw the idea open to the public. Then, when a rival began making the improved form of axe, the inventor would derive no advantage from his initiative, thought, and labor.

The concept of title didn't help, for the man who bought the improved axe owned the axe rightfully. Of course, if the inventor chose to keep the thing a secret he could keep ownership of the idea — but that would be a Spartan concealment.

It gradually became recognized that a man should have a property right in his invention just as much as he had to his own axe, or his dog, or his home, or anything else he worked for and got by his own efforts.

## • Provision for legal patent rights

But the law changes very slowly. It is like the Bourbons, who learn nothing and forget nothing. It has taken ages for this simple right of property in inventions to be recognized.

This conviction of the property right in inventions grew acute with the advent of that stage of economic development known as the division of labor and the factory system — the Industrial Revolution.

Not altogether by accident, but with pronounced causal connection, there occurred just at this juncture a great event — the American Revolution. If you should be interested in the relation between the Industrial Revolution and the American Revolution, I might pause to tell you.

The American Revolution and the Constitution to which it gave rise emphasized or idealized the rights of the individual. The Constitution, and the laws which followed it, clothed the inventor with more than mere property rights. The invention must have absolute novelty and hence the act of invention is emphasized. It is not enough that a new and useful invention has been brought into being. Some one must be the inventor, and he must have the quality of invention in him. This makes the invention a personal matter, and the inventor is treated as a special individual of an exalted character, instead of a normal individual doing the work that is expected of him.

We can all recognize the necessity for patents as a means for protecting an inventor in a way in which he is incapable of protecting himself.

"Title" was a convenient thing to relieve a man of the necessity for physical violence to recover his wrongfully taken physical property, but conceivably, a man could physically recover stolen property. But physical violence would never be capable of recovering a stolen idea. *Title to an idea* is not an easy concept.

The concept of a patent as a monopoly granted to one who introduced a new manufacture into the Kingdom is quite old, and was recognized as an established institution by the Statute of Monopolies in the reign of King James I. Prior to this legislation, patent rights had been cast into the same legal form as *predatory* monopolies. After predatory monopolies were extinguished, patents for inventions continued in the same form. Casting the grant for a patent for an invention in the form of a predatory monopoly has been one of mankind's misfortunes.

With the invention of the steam engine came the Industrial Revolution, the factory system, and the division of labor (all so well established that their names sound strange).

The Industrial Revolution brought about the American Revolution and the French Revolution. This was a movement by mankind broadly asserting the right of the individual to live, to hold property, and to have a voice in his own political government.

The political philosophy of the American people, as expressed in the Constitution and the statutory law enacted thereafter, appears to assert all rights, even the right to ideas, to be natural rights, existing by virtue of the divine endowment of man. The Constitutional provision contemplates the enact-

ment of legislation by Congress to grant exclusive rights to authors and inventors in order "to promote the progress of Science and useful Arts." It appears that the rights of the authors and inventors to their respective writings and discoveries are to be made subservient to the good of the public. That appears a bit strange in a philosophy as individualistic as that of the time of the Constitution.

If the right of the individual to own his ideas is a natural right, that is, one inherent in the existence of the individual, why should he have that right secured to him for only seventeen years? Why, if he is the owner of an idea, and if the Patent Law recognizes his property right, isn't his title good forever? Who has a superior title if he has not? He had it first, and he took it from nobody else. If anybody is entitled to a property right in an idea, he, the inventor, is; but the United States Government says he shall have it for only seventeen years, then he loses it. If I discovered a new island, and claimed it in the name of the United States Government, and occupied it, I think the Government would not insist on throwing the property open to everybody, including foreign citizens. Or, if I lost a gold ring, even if it were not found for seventeen years, that would not change my right to recover it; my title would be just as good as ever.

## • The nature of the patent right

1. Some decisions say that a patent is a contract between the Government and the inventor. In return for the disclosure of his invention which he makes to the public, he is allowed the exclusive use of it for seventeen years.

This fails to satisfy reason. If the patent is a contract between the inventor and the public, how can the public, or any one member thereof, back out of the contract by saying the contract should not have been made? Even if I enter into a bad bargain the courts will not change the bargain. If fraud or complete lack of consideration be shown, the court will declare that no actual contract was made, but short of that a man's contract is "his own funeral." Yet a patent, unlike ordinary contracts, may be terminated or invalidated for reasons other than fraud or complete lack of consideration.

2. Some decisions view the patent as a grant of a right to recover an indefinite amount from the public, such grant being in the nature of a reward to the inventor for his act of invention. On the theory that the public is the real beneficiary, this theory is quite defensible, but it puts the inventor in a light which does not agree with his true character. He is trying to hang on to his invention and make money by marketing it, whereas that theory makes him interested in levying tribute upon the public. The patent is granted, not for the good of the individual, but for the good of the public. The theory of reward appears to lead away from the intent of the Constitutional provision. It emphasizes the monopolistic and offensive character of the grant, whereas the better philosophy views the patent grant essentially as a constructive contribution for the benefit of the public "to promote the progress of Science and useful Arts."

3. Some decisions and writers say a patent is property created by the grant of the Government, like a government bond or fiat money. If we examine this theory we may observe that a patent has few of the attributes of property. The United States patent is not taxed; no working is required; it cannot be revoked.

If the Government grant creates the property, is it not odd that the judiciary can destroy the property? A patent is granted under an authority in the Constitution which is as direct and solemn as the authority for the judiciary which declares the invalidity of the patent.

4. Some writers consider that a patent is but a governmental recognition of the natural and inherent right of the individual to have full power of ownership of his mental creations as fully as his other forms of property. His ideas are his own property. The government says it merely "secures" to the inventor that which was his, although insecure before.

But the difficulty with that view is the necessary argument that a man has possession of an idea because he can refuse to disclose it to others. His alleged ability to suppress it is said to be proof of complete ownership. That means the only way a man can be sure to own an idea is not to use it. And what is he going to do about ownership if some later inventor comes forward with the same idea? How can he then demonstrate his alleged property right?

5. Another comment on the patent right is that it is purely negative or nugatory. The patent grant gives no right to use the invention but only to obstruct use by others. In other words, the patentee's right is a nuisance right or a "dog in the manger" right. The inventor discloses in the patent an invention by the use of which wealth may be added to industry and he is then empowered by the Government to prevent others from using the invention.

The invention is constructive, but the patent right is obstructive. Does it not seem that the theory is wrong? Should not the system of granting patents be based upon enabling the holder instead of disabling the non-holder of the grant? The ideal system would be to grant the positive right to make, use, and sell a useful addition to the world's knowledge instead of a nugatory or negative right to prohibit.

A patent is often defined as being merely the right to prevent others from making, using, and selling the protected device. Perhaps a better way to look at it is to say that the Government entrusts

the inventor with the opportunity and duty to exploit his contribution for the benefit of the public and gives him seventeen years in which to bring his invention into public use. His duty is that of the head of a department in an enterprise, charged with the successful conduct of that part of the enterprise, and he has a positive duty to perform rather than a mere negative right.

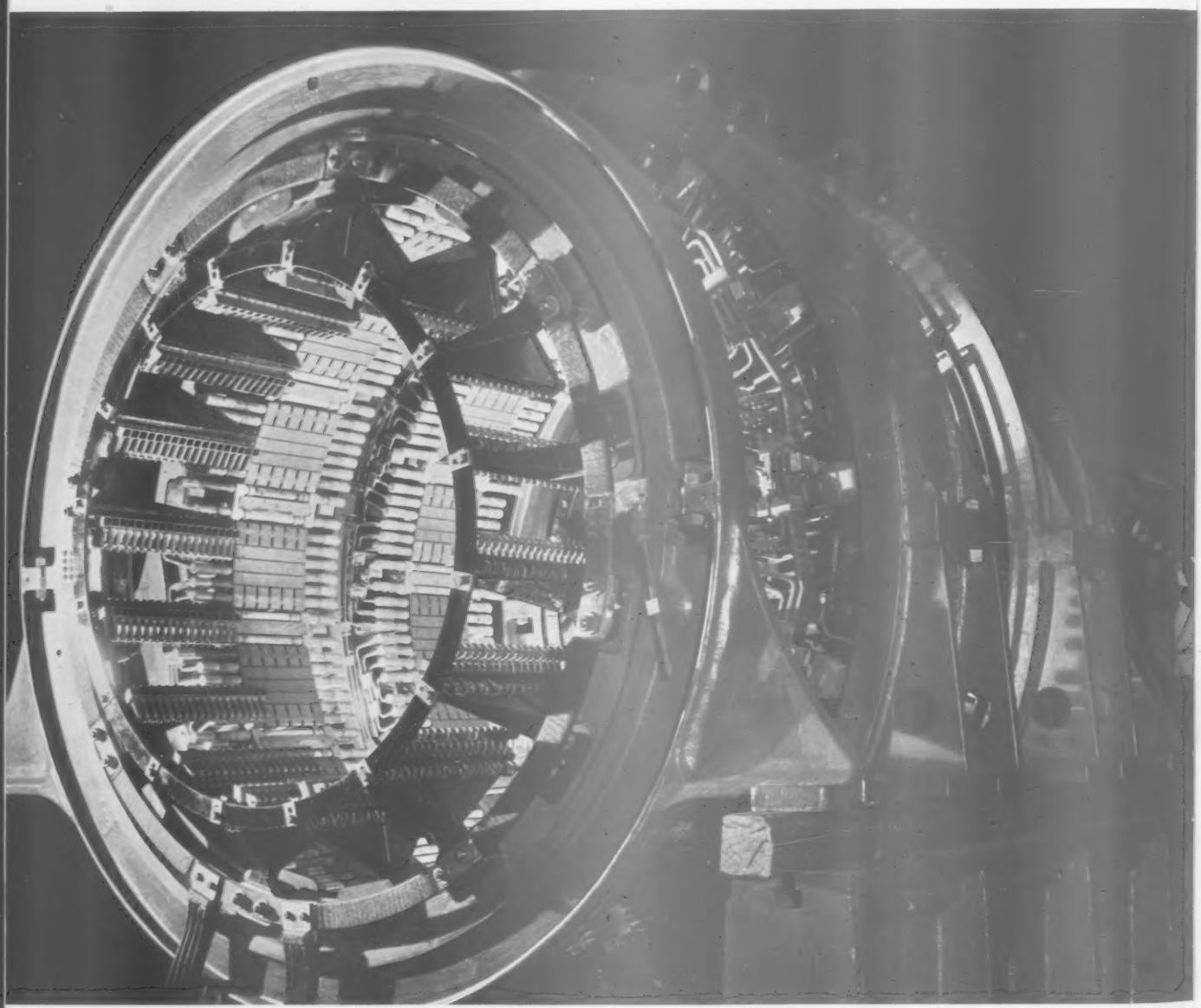
### • Patent grant involves human and property values

The unsatisfactory explanation of the patent grant as a form of property and the peculiar character of the treatment of an infringer leads to the conclusion that a patent right consists essentially of two dissimilar values. One is a property value, and the other is a human right value.

If we go back to the Constitution as a whole, and to the Declaration of Independence which preceded it, the values involved in the grant become much more understandable.

The genius or concept of the Constitution lies in the recognition of the rights of the individual. This includes two phases: first, his relation to property, and, second, his relation to people. The Constitu-


## MOTOR GENERATOR SET YOKES



tion, particularly in the Bill of Rights, guaranteed the right to hold property, and it guaranteed the human rights, presumably, of life, liberty, and the pursuit of happiness. The patent grant in the United States partakes of those two values, namely, the property right value and the human right value. We may also observe that these two values appear in the grant of patents under other systems, that is, in other countries, but with the emphasis placed differently.

A man's invention is something which is peculiarly personal to him. It is the fruit of his life's experience. The United States system takes very definite cognizance of that human value in requiring that the inventor, and he alone, execute the application for patent. Hence, one great value of the United States Patent System is its spiritual value in encouraging the common man to raise himself in the esteem of his fellows and to gain a competence. This value of the patent as a stimulus and encouragement is beginning to be recognized in other countries. These other nations are beginning to sense the spiritual or human-rights value in the invention and patent.

At the International Conference in London (1934) for the protection of industrial property, there was introduced the provision (Article 4 Ter.) to the effect that —

> "The inventor shall have the right to have his name appear, as inventor, on the patent."

At this same conference, a number of proposals to extend the free period during which taxes were not to be levied were made. This indicated plainly the shifting of the emphasis from the property value of the patent to the human-rights value which is occurring in the mind of the world, and particularly in those countries where heretofore the property value has been dominant.

The status of the average inventor now (1937) is in the aggregate different from his status when the American system was instituted in 1836. At present the average inventor is in the employment of a corporation, and he participates but little in the benefits accruing from the patent grant.

If the inventor be not employed by a corporation, and his invention is not assigned to a corporation, he is not in position to manufacture the invention, because manufacturing for the American market requires expensive machinery of production, and this the individual is rarely able to command.

Hence, under present conditions, the patent right has been converted in the hands of the assignee into a purely property right value, and the human-rights value of the patent system is being considered as secondary in the United States. Thus we see that the United States patent system and foreign patent systems are approaching each other more nearly in that in foreign countries the human-rights value is being recognized to a greater degree, whereas because of changes in economic conditions and the greater development of the arts, the human value is being lost and the property value emphasized under the American system.

## • Changing economic concepts

Do the signs of the times indicate any fundamental imminent change in the United States system?

No one can say positively, but a brief review of the economic situation of the world and of the United States in particular is interesting in this connection. In three periods of the world's history, we can recognize important differences in the economic situation of the people.

Up until the time of the Industrial Revolution there had always been a scarcity of necessities. After the Industrial Revolution a reasonable supply of necessities was available, and since the World War there appears to be an overproduction of necessities. These changes in conditions have wrought changes in the emphasis upon human rights as compared to property rights.

From the earliest records of man down to the Industrial Revolution, man's progress has been marked chiefly by developments in

1. Instruments of destruction.
2. Integration and disintegration of political power characterized by the minority coercing the majority, politically and economically.

Then came the Industrial Revolution followed by the American Revolution and the French Revolution, which emphasized the right of the individual to hold property and to be secure in the reasonable enjoyment of life.

From the time of the Industrial Revolution to the World War, civilization is characterized by

1. Development of instruments of production with a resultant reasonable supply of necessities.
2. The concept of political rule by the majority.
3. The concept of *laissez faire* (free competition).

Then came the World War followed by the Russian Revolution and the World Panic. This move-

ment emphasized the right of the individual to a minimum participation in necessities; in other words, the right to enough to keep from starving.

The present period which is really just begun is characterized by

1. Development of instruments of far reaching intercommunication and transportation: radio, automobile, television, movies.

2. The concept of economical control of the minority by the majority — a planned economy, i. e., competition controlled or eliminated.

## • The overproduction of necessities

The overproduction of necessities (when compared to effective consumer demand) has given the most astonishing twist to the philosophy of government in the United States, particularly as affecting the concept of the basic rights of the individual. Property rights during world scarcity are sacred, because they may mean the difference between life or death. A full supply of grain or potatoes may mean life or death of the entire community in a region where transportation and inter-communication is lacking. An example of the high regard for property values necessitated by conditions is illustrated in the food cache of the wilderness or in the Far North. If this is lost or dissipated, it may mean death through starvation.

Another illustration which we have heretofore encountered is the question of saving for old age. Loss of such savings literally meant starvation under previous conditions. But now WPA provides a job if you can work, and Old Age Security feeds you when you are too old to work.

Property rights are now declining in importance basically because of overproduction. According to the old British law, they would hang a man for stealing a sheep. Imagine how far you would get with such a law if the countryside were overrun with sheep. You can't even put a man in jail overnight for stealing a pig when the Government decides to kill 6,000,000 pigs to get rid of them. After all, the scarcity of property has a great effect upon its value.

Human rights are in the ascendency. The economic control of the minority by the majority has now arisen, and we can see the following remarkable situation in the day's news:

1. The individual has a right to his job. That job is superior to the property right of his employer in the machinery connected with the job. If you have any doubt about this, study the legalistic features of the recent "sit-down" strike at the General Motors plants in Michigan.

2. "No one in the United States is going to starve." The WPA or some other agency must give you the right to work.

3. The "majority" now provides unemployment insurance.

4. The "majority" provides Old Age Security.

5. Another astonishing change in the policy of the United States is the Neutrality Laws. The "majority" have said that they will not protect the property of individuals in war time.

## • Effect on American patent system

Remembering that the concept of the patent right is a special and peculiar case of the combined right of the person and the thing (human rights plus property rights) in no other country is the emphasis so strong on the human right as in the United States. All other countries put more emphasis on the property right. But we can expect according to the present trend an extension of the human right and a modification of the property right. The question is how will this probably occur?

## • For the inventor

For the inventor, reforms along the following lines are highly probable:

1. Increased participation by the inventor in the benefits derived from the invention, even though the patent has been assigned, as is now the practice under the Austrian Patent System.

2. Granting of patents by the Patent Office in less time and at less cost.

3. Simplification or elimination of Interference Practice in the Patent Office.

4. Stronger support of patents in the Courts.

5. Compulsory bargaining for a license as a substitute for an injunction preventing the loser in a patent suit from working under the patent in suit.

While the thoughts I have expressed are my own opinions, I think that there is a large body of facts, some of which have been mentioned above, which support the conclusions reached. Although some of us do not like the direction in which things are going, it is only the intelligent thing to recognize the trend, and perhaps influence it, rather than close our eyes to it because we may disapprove of it.

# POSSIBILITIES OF AUTOMATIC POWER FACTOR REGULATION IN DISTRIBUTION FEEDERS

• E. H. Stivender
SWITCHGEAR DIVISION . . . ALLIS-CHALMERS MFG. CO.

For years some public utilities have encouraged power consumers to provide power factor correction in their plants. The practice has become so highly important that an increasingly greater number of utilities serving industrial areas are offering attractive inducements for consumers to install corrective apparatus. This apparatus sometimes runs into appreciable expenditures by the consumer; and when he does make such investments, it is naturally with the expectation that he will be duly compensated within a few years.

In the past, power factor corrective equipment consisted of fixed quantities of static condensers or of synchronous equipment. There now seems to be considerable possibility of improving operating conditions at a considerably lower cost by using a combination of fixed and automatically controlled static condensers so as to automatically maintain good power factor.

By automatically controlling the power factor, it is possible to have nearly the same voltage at each end of a distribution feeder at all times; and in some cases, the more inductive reactance there is in a line, the better the voltage regulation will be. That is, whereas the ordinary feeder is built to bring the lines as closely together as possible in order to reduce reactance, the use of automatically controlled capacitance permits the lines being placed as far apart as possible, providing better insulation between lines and better voltage regulation. In addition, there is a worthwhile reduction in losses all the way back to the generating station. By placing reactors in the line it is possible to get even better voltage regulation.

The equipment for automatic power factor regulation consists of control apparatus arranged to insert or remove automatically parallel capacitance in the circuit, thereby maintaining a given value of power factor regardless of changes in the load conditions. Owing to the fact that fine step regulation of capacitors would probably be economically impractical for most installations, no suggestion is made that this equipment replace feeder type voltage regulators. The equipment would, in many cases, supplement voltage regulators and in others serve where voltage regulators are not feasible.

It is generally known that most of the voltage drop in distribution lines is due to lagging current flowing through inductive feeders. While the feeder voltage regulator maintains constant voltage regardless of the amount of wattless current flowing, the power factor regulator eliminates most or all of the wattless current, thereby improving the inherent voltage regulation of the feeder often as much as 500 per cent. If induction type voltage regulators are used the wattless component in a feeder may be considerably increased adding considerably more losses to the system. The power factor regulator, although admittedly not giving the same voltage regulation, reduces losses, and as will be shown, gives desirable voltage regulation on some of the usual types of feeders supplying inductive loads.

Capacitors could be added which would permit the power factor to become increasingly leading as the kw load increases in order to provide flat voltage regulation where such operation is desired; it is felt, however, that in practically all cases the voltage regulation resulting from maintenance of unity power factor would in itself be sufficient. Better regulation than this would naturally require additional capacity in the condensers and hence would increase the cost.

With the usual fixed capacity installations for power factor correction, the entire condenser unit is in service at all times, which results in considerable leading current flowing in the line during light loads. In many feeders, this leading current causes excessive rise in voltage at the distribution end of the line at light load periods shortening the life of apparatus affected by voltages higher than normal, such as incandescent lamps and radios. Automatic regulation of the capacity connected in the circuit prevents voltage rise above normal by controlling the value of leading power factor. Heavy leading currents also contribute energy losses in distribution equipment similar to those due to lagging currents.

## • Description

It is to be understood that the regulating device under consideration is not a reactive kva regulator. It regulates for zero reactive kva when set for unity power factor; but at all other settings it regulates for constant power factor allowing the reactive kva to vary directly with the kw. A reactive kva regulator would not provide the flexible service offered by the power factor regulator. The regulating element of this unit is similar to that of a contact-making voltage regulator element, solenoid operated, of rugged construction and high torque. It is not simply a contact-making power factor meter or a synchronous motor with a-c field excitation. The number of taps on the condensers determines the smoothness of regulation. More capacity can be added as conditions require.

The equipment is set up similar to the usual fixed condenser installations except that the frames are designed to allow the condensers and control in a compact unit.

The tap changing apparatus consists of oil-immersed contactors, magnetically operated for 2300 and 4000 volt units, and steel-enclosed, air-break contactors for lower voltage units. The equipment is designed especially for power factor regulators—compact and capable of standing hundreds of operations daily. On distribution feeders the requirements are generally for outdoor equipment, and provision for this can be made by housing the assembly in steel.

**Fig 1 — 2300 volt distribution feeder showing connections of parallel type automatic power factor regulator and the line and transformer impedances.**

Protection against overvoltage may be provided by an overvoltage relay set to limit to a definite amount the capacity in the circuit. Protection against short circuits may be obtained by the use of individual fuses. A main circuit breaker with overload relays is also provided with each unit.

A control handwheel affords manual operation. Settings for different regulated power factors are made by adjusting a knob on the regulating element. Single-phase or three-phase regulation can be provided.

## • Voltage regulation

The following calculated data indicate the advantages of automatic power factor regulation for various applications:

**Case 1. Fixed capacity with no regulating equipment.** The sketch of Fig. 1 shows a simple system consisting of a single- or three-phase transformer supplying a feeder to which a reasonably balanced industrial load is connected. An automatic power factor regulator is connected near the load. The transformer is rated at about 400 kva, being of such size as to accommodate additional load in the future. The ratio is 13800/2300 volts.

$Z_t$ = 0.54 ohms
$R_t$ = 0.23 ohms
$X_t$ = 0.4 ohms (total primary and secondary impedance)

In the feeder,
$Z_f$ = 2.58 ohms
$R_f$ = 0.65 ohms
$X_f$ = 2.5 ohms

The load is 2300 volt equipment rated at 242 kw, 75% power factor. Putting this in terms of impedance,

$Z_L$ = 16.4 ohms
$R_L$ = 12.5 ohms
$X_L$ = 10.85 ohms

Adding impedances $Z_t$, $Z_f$, and $Z_L$, the total impedance Z is

13.18 + J13.75 ohms.

If 13,800 volts are on the primary side of the transformer, the load current will be

(2300/13.18 + J13.75)
= (83.5 — J87.1) amp
= 120 amp

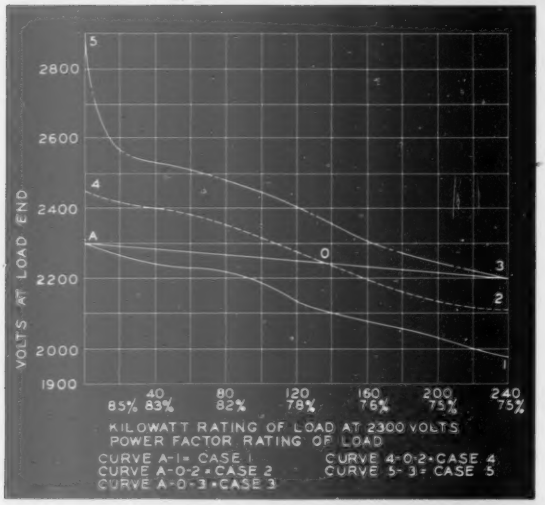



**Fig. 2 — Computed voltage curves at receiving end for different values of regulated and unregulated capacitance, as discussed in Cases 1 to 5. These curves refer to the feeder of Fig. 1.**

The voltage at the load will be
$(83.5 - J87.1)\ Z_L$
$=(83.5 - J87.1)\ (12.13 - J10.85)$
$=1975 - J166$ volts
$=1980$ volts

The per cent regulation of the feeder is
$(2300 - 1980)/2300 = 13.9\%$

This figure is approximate since the power factor of the load will probably change with the voltage at that end, depending upon the kind of equipment composing the load, but it is sufficiently accurate to provide the required data for sound discussion.

**Case 2. With automatic regulation for minimum of 95% power factor.** Now assume an automatic power factor regulator to be installed with sufficient kva capacity to give 95% power factor at full load. (The expense is sometimes too great to provide capacity enough to give 100% power factor at full load unless the service requires it.) In the case of Fig. 1, there are 213 reactive kva when there are 2300 volts at the load; the required condenser capacity to bring the power factor at the load from 75% to 95% at 2300 volts is 112 kva.

At full load there would be 242 kw at 95% power factor. Putting this in terms of impedance, $R_{L1}=19.75$ ohms and $X_{L1}=6.5$ ohms.

Adding this to the line and transformer impedances $Z_r$ and $Z_t$ given in Case 1, the total impedance is

$Z_1=20.63+J9.4$ ohms

With the same transformer ratio, the current will be

$2300/(20.63+J9.4)$
$= 92.5 - J42$ amp
$=101.2$ amp

The voltage at the load will be
$(92.5 - J42)\ Z_{L1}$
$=(92.5 - J42)\ (19.75+J6.5$
$=2098 - J230$ volts
$=2110$ volts

The per cent regulation of the feeder is
$(2300 - 2110)/2300 = 8.25\%$

The power factor would reach unity at about one-half load.

It will be noted that full rated load is not furnished at the distribution end due to the voltage drop in the line.

**Case 3. With automatic regulation for 100% power factor at all loads.** Suppose the automatic power factor regulator had sufficient capacity to make the load power factor 100% at full load. This would require a 213 kva condenser.

Two hundred forty-two kw at 100% power factor, 2300 volts, is equivalent to an impedance of $Z_{L2}=21.9$ ohms, in which $R_{L2}=21.9$ and $X_{L2}=0$ ohms.

Adding this to the line and transformer impedances $Z_r$ and $Z_t$ given in Case 1, the total impedance is $Z_2=22.78 - J2.9$ ohms.

With the same transformer ratio, the current will be

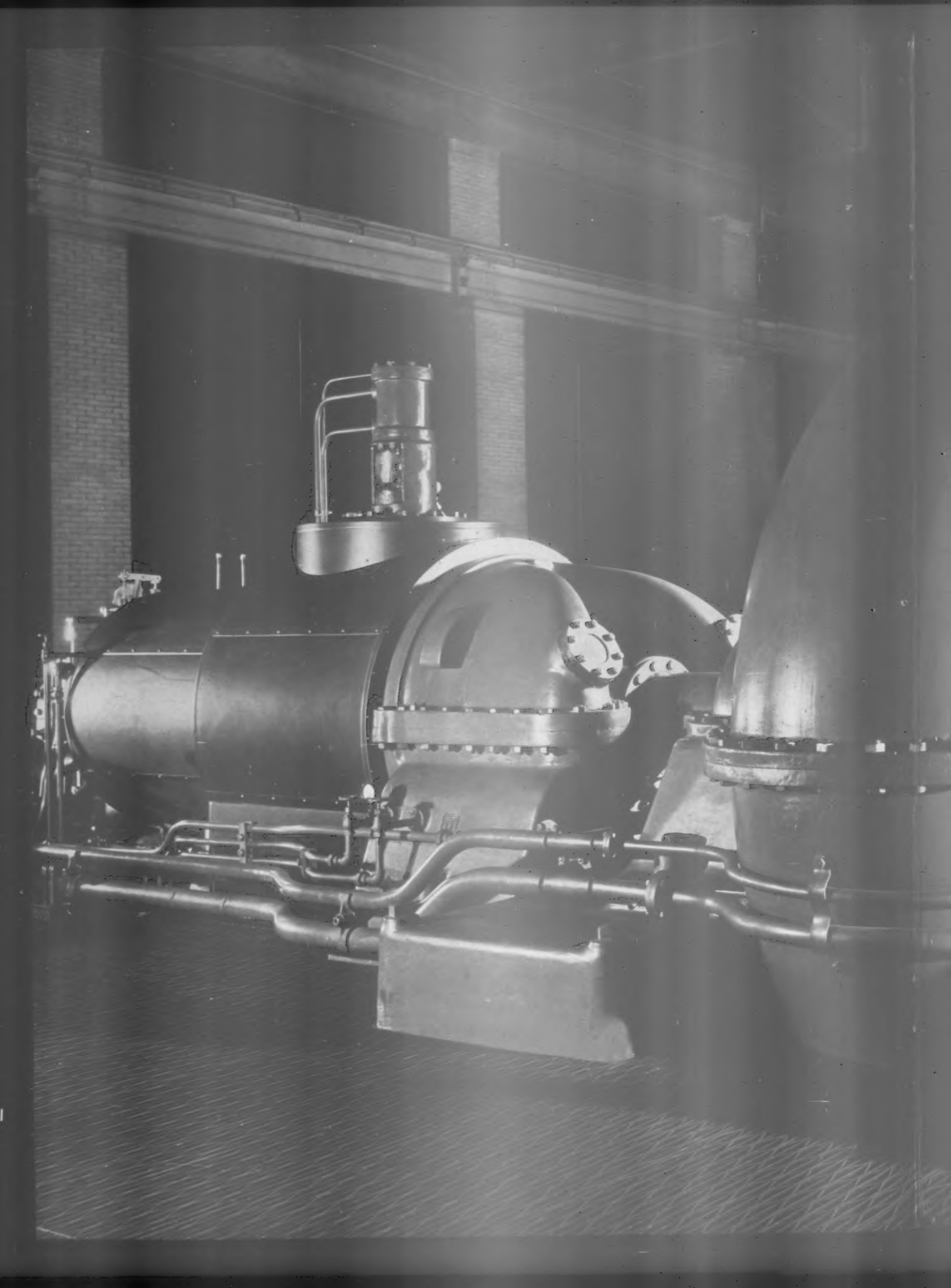
$2300/(22.78+J2.9)$
$=100 - J12.7$ amp
$=100.8$ amp

The voltage at the load will be
$(100 - J12.7)\ Z_{L2}$
$=(100 - J12.7)\ 21.9$
$=2190 - J278$ volts
$=2210$ volts

The per cent voltage regulation is 3.9%.

**Case 4. With fixed capacity and no automatic regulation—minimum of 95% power factor.** In Case 2, let there be a fixed condenser installed instead of the power factor regulating equipment and let the minimum load be 20 kw at 85% power factor. This might be an industrial plant with only a few lights burning at night with some small fans and pumps running, or it might be an office building. Twenty kw at 85% power factor means there are 12.4 lagging reactive kva in the load equipment. Subtracting this from the 112 leading kva of fixed capacity and neglecting the 0.2% losses in the condenser, the total reactive kva of condenser and load is 99.6 reactive kva. The load being 20 kw, the power factor of condenser and load will be 19.7% leading. This is equivalent to an impedance of $Z_{L3}=51.3$ ohms (capacitance).

Adding these impedances to the line and transformer impedance given in Case 1, the total impedance of transformer, line, condenser and load is $11.18 - J48.4$ ohms.



With the transformer ratio given in Case 1, the current is

$$2300/(11.18 - J48.4)$$
$$= 11 + J44.7 \text{ amp}$$
$$= 46 \text{ amp}$$

The voltage at the load will be

$$(11 + 44.7)\, Z_{13}$$
$$= (11 + J44.7)\,(10.3 - J51.3)$$
$$= 2408 - J104 \text{ volts}$$
$$= 2409 \text{ volts}$$

Hence, there is a rise in voltage at the receiving end of 109 volts, or about 4.7%, which fact is sufficient in some cases to discourage the use of fixed condensers. Obviously the only way to get good power factor at the load safely and economically is to use variable capacitance, automatically regulated.

At times when there is no load at all on the feeder, the voltage will reach higher values, as may be seen by curve 4-0-2, Fig. 2.

**Case 5. With fixed capacity and no automatic regulation — minimum of 100% power factor.** In a similar manner it may be shown that if the capacitance of Case 2 were not regulated and the minimum load of Case 4 exists, the power factor would be 9.9% leading; the current would be

$$14.5 + J97 \text{ amp}$$
$$= 98 \text{ amp}$$

and the voltage

$$2567 - J126 \text{ volts}$$
$$= 2567 \text{ volts}$$

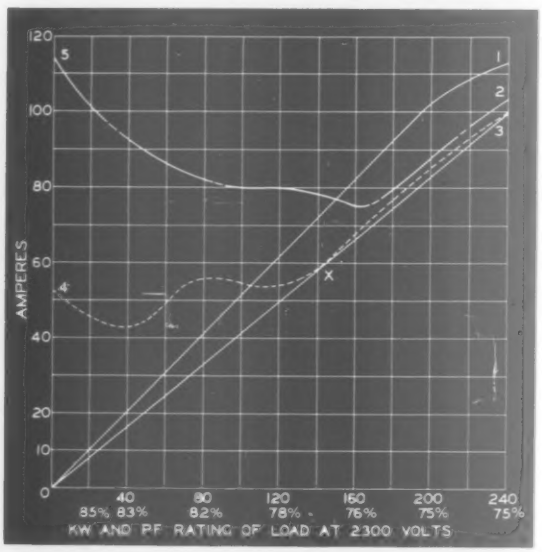



**Fig. 3 — Computed curves of line currents. Curve 0—1 is for Case 1, Curve 0—X—2 is for Case 2, Curve 0—X—3 is for Case 3, Curve 4—X—2 is for Case 4 and Curve 5—3 is for Case 5. Refer to Fig. 1.**

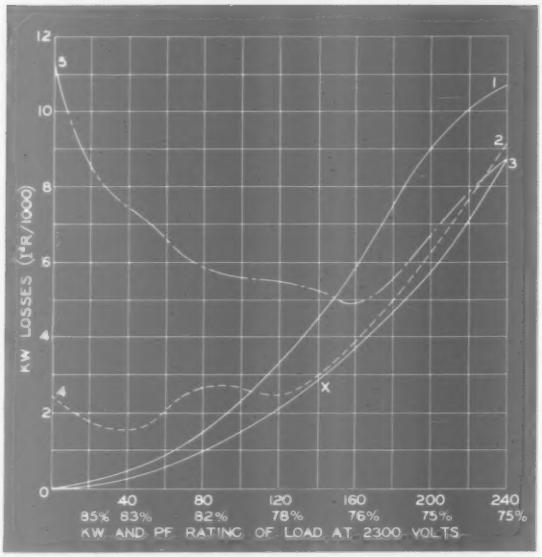



**Fig. 4 — Computed line and distribution transformer losses. Curve 0—1 is for Case 1, Curve 0—X—2 is for Case 2, Curve 0—X—3 is for Case 3, Curve 4—X—2 is for Case 4 and Curve 5—3 is for Case 5. These curves do not take into account the small losses (0.2%) in the corrective condensers nor the corrective equipment transformer losses, should such transformers be used. Refer to Fig. 1.**

The ratio of series inductance in the line and transformer to the capacitance in the condenser has reached such a point that the condition of resonance is becoming manifest. Curve 5—3, Fig. 2, illustrates voltages for different loads and power factors. Note the rise in voltage at no load. The no load losses in this case would be greater than the full load losses, making the fixed condenser very undesirable from an operating point of view even if the voltage rise could be tolerated.

Consideration of the losses for the various cases will be given in the section under "Line Current and Losses."

**Voltage Curves.** In Fig. 2 are given computed curves for Cases 1 to 5, illustrating the voltages at the load for different rated loads and power factors. In some feeders, the power factor will be lower at light load than at full load, and in others it will be higher, depending upon the number of small motors, transformers, lights, etc. This is simply an arbitrary case characteristic of many feeders.

The loads marked are *rated* loads based on 2300 volts at the load end; but, since rated voltage is not always reached at full load current, the actual load in kw will not be the same as marked, varying for different voltages at the load end. The actual loads can be computed from Figs. 2, 3, and 4

## • Regulated capacity to maintain constant voltage at a receiving point

**Methods of voltage regulation.** As previously stated, the capacity may be regulated in such a

manner as to maintain constant voltage at the load end. Furthermore, by the use of a line drop compensator, constant voltage may be maintained at some point other than where the power factor regulating apparatus is connected. The power factor regulating apparatus may be used with the load compensating connection, as mentioned, or a voltage regulating element may be used instead.

Where the power factor regulating element is employed, it is necessary to use load compensation or to set the regulator for a given leading power factor, whether the voltage is to be maintained at the point of connection or at some other point. This leading power factor setting is determined by the loading conditions and the constants of the line. By maintaining a constant leading power factor for all loads, a satisfactory degree of voltage maintenance can generally be obtained; however, the use of this method allows the voltage to rise slightly at light loads. By the use of load compensation on the power factor element, the leading power factor is a function of the load current and flat voltage is obtained for all loads.

The action of a voltage regulating element differs from that of the power factor regulation element in that the former tends to increase or decrease capacity to hold a definite line voltage, regardless of either voltage conditions at the sending end of the line or the wattless current in the line. A power factor element would tend to make the load voltage always a function of the sending voltage; that is, the power factor regulator would generally be set to keep the load voltage nearly equal to that at the sending end. For this reason, line loss due to either leading or lagging current can be reduced to an absolute minimum and flat voltage maintained at the load by using some form of voltage regulating equipment at the sending end and power factor regulation with or without load compensation at the receiving end. This method is adaptable in cases where voltage regulating equipment is in use at a generating or distribution point; then power factor regulating equipment with or without load compensation is beneficial at the receiving points.

If power factor regulation is considered before a distribution line is constructed, by spacing the conductors on the poles farther apart than would ordinarily be, greater inductive reactance can be obtained, and hence less condenser capacity for the regulating equipment is required. Therefore, while ordinarily the conductors would be placed as close together as possible in order to reduce reactance, two advantages can be gained by spacing them farther apart when power factor regulating equipment is to be used—greater insulation for the line and lower cost for the regulating equipment. In some cases, it might even be economical to install reactors in the line. This method would allow the use of high speed operation where it is desirable to place a large amount of capacity across the line in a short space of time, as, for instance, when large motors are started.

The practice of changing the regulator taps on the supply transformer in order to compensate for the greater line drop with increasing loads would in many cases be eliminated, since the action of the automatic power factor correction apparatus would make the receiving voltage on a feeder nearly equal to the sending voltage. Likewise, the objectionable variable sending voltage obtained with ordinary regulating equipment would be eliminated and flat voltage at one end of a feeder would not be sacrificed to provide the same characteristic at the other end. Hence, power factor regulation promises improved service for power consumers at both ends of a feeder.

Where it is desired not to have the regulating equipment operate on every fluctuation in load conditions, a definite time relay can be introduced so as to hold the control circuit open for a given time after a change occurs; then, if the change is not sustained, the control equipment does not operate.

Where the no load voltage is likely to reach excessive values on the receiving end of the feeder (see Case 5), such as when the line would be de-energized at full load and later be re-energized with no load connected, provision can be made for running the regulator back to zero before the contactors begin to close.

By the use of a "forcing" arrangement the complete bank of condensers can be made to be almost instantaneously placed across the line when excessively low power factors occur. This would be useful for where large motors are to be started.

**Comparison of the two methods of voltage regulation.** In any method of voltage regulation, the line losses are increased when constant voltage is maintained at a receiving point. Conventional voltage regulating equipment, as heretofore used, has nearly always been employed to greatest advantage at the sending end of a feeder. Line losses are reduced by virtue of the higher transmission voltage produced by a voltage regulator operating with line drop compensation; that is, the kva of the feeder is increased by raising the voltage. If such a regulator were located at the receiving end, the kva would be increased by the increased current. Hence, since losses vary as the square of the current, the proper position for the conventional feeder voltage regulator is at the sending end.

Voltage regulation by means of condensers naturally makes the receiving end the preferable location, since the principle of operation is the elimination of lagging current flowing through an induc-

tive line. Such regulation, of course, requires additional capacity in the power factor corrective equipment.

## • Line current and losses

The kw loss in a static condenser is approximately 0.2% of the kva input to the condenser, although low automatic regulation further reduces losses in a system by removing condenser kva from service when it is not needed. Since the kva capacity of a condenser varies with the square of the applied voltage, it is often a great saving in first cost to provide step-up transformers and high voltage condensers when power factor correction is desired on low voltage circuits. The full load losses of such transformers are 1.5 to 2%, and automatic regulation reduces this as well as condenser loss by reducing the load on the transformers.

The curves in Fig. 3 show the current for the five cases discussed in Section 2, and Fig. 4 shows the line and transformer losses in kw. Figure 4 is only for the losses in the line and feeder transformer; losses on the high tension line are not included nor are the slight losses of the power factor correction equipment.

**Case 6. Losses in a feeder employing the power factor method of voltage regulation.** The following discussion is based on the line constants and load conditions outlined in Case 2.

Suppose it is desired to obtain a slightly rising voltage at the power factor regulator. This would require total capacity of approximately 333 kva, or 120 kva additional to that required in Case 3.

Full load rating of the load equipment is 242 kw at 75% power factor, 2300 volts. The placing of 333 kva of capacity in the regulator brings the total power factor of the load and condenser to approximately 90% leading at full load; the total kva is 270 and the current at 2300 volts is 117.5 amps. The total equivalent impedance of the load and condenser is $Z_{L6}=19.6$ ohms, in which $R_{L6}=17.6$ ohms and $X_{L6}=8.62$ ohms. Adding this to the total impedance of the line and transformer, .88+J2.9 ohms (see Fig. 1), the total impedance of line, transformer, condenser and load is

$$18.48 - J5.72 \text{ ohms}$$
$$=19.4 \text{ ohms}$$

With 13,800 volts on the primary of the distribution transformer, the line current is

$$2300/19.4=118.5 \text{ amp}$$

The voltage at the load is

$$118.5\ Z_{L6}$$
$$=118.5\times 19.6=2320 \text{ volts.}$$

Thus, a rise of 20 volts at full load is obtained between the sending and receiving ends. If it is desired to have 2300 volts, the regulator will be set so as to insert a slightly smaller amount of capacity in the circuit.

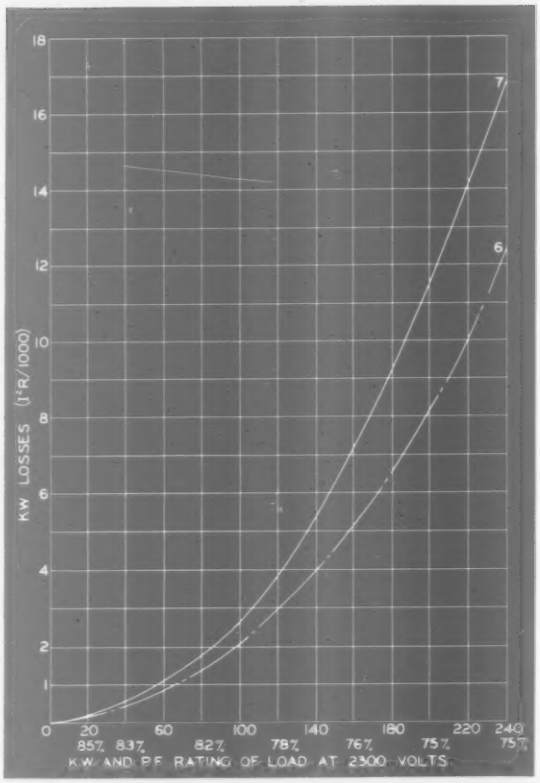


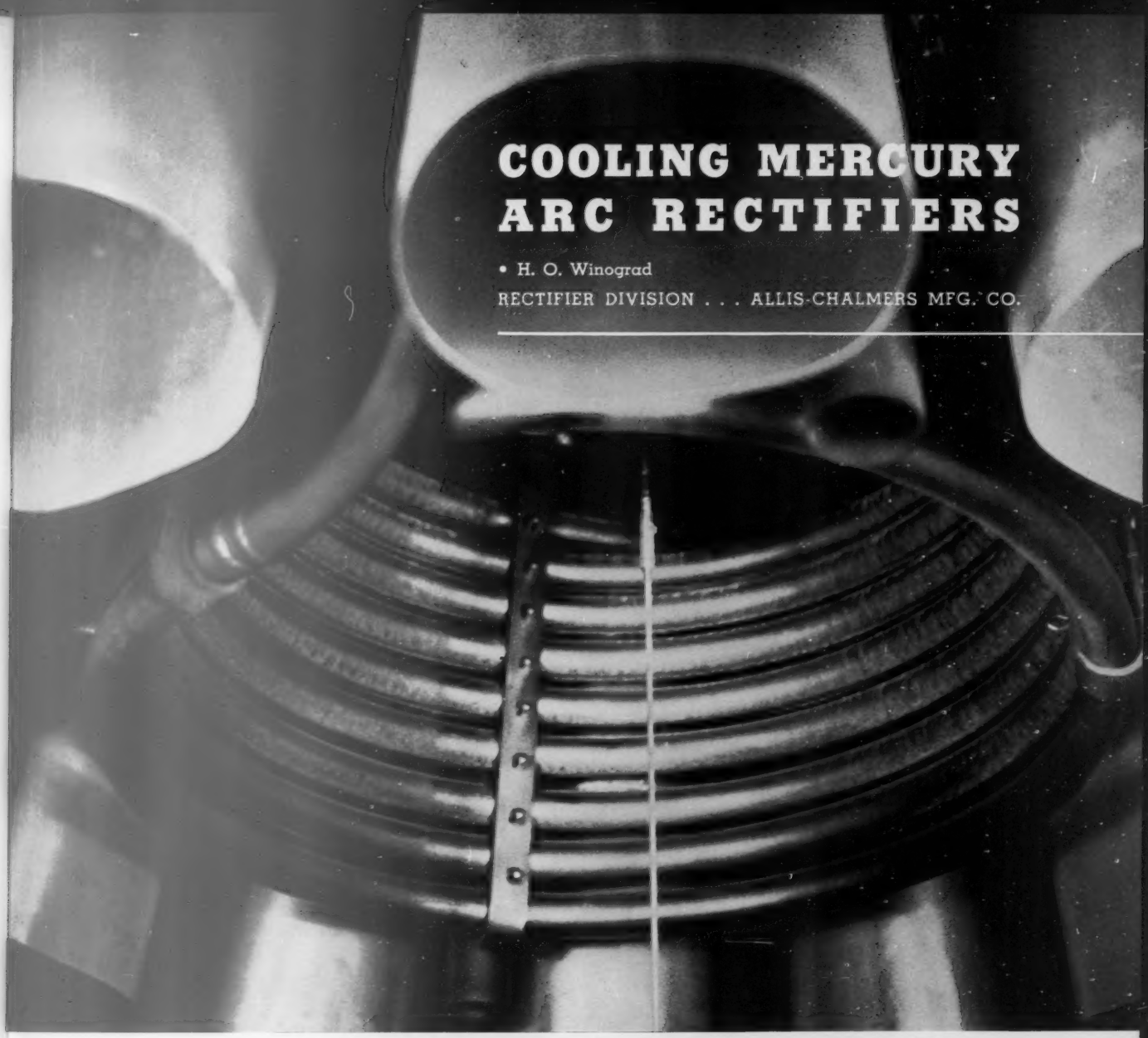

Fig. 5 — Comparative losses in the line of Fig. 1, using compounded voltage regulation at the sending end as against compounded regulation by automatically varied capacitance at the receiving end. Curve 0—6 is for Case 6 (capacitance regulation) and Curve 0—7 is for Case 7 (voltage regulation—by generator or feeder regulator or otherwise). Line and distribution transformer losses only are given.

The losses incurred by this type of voltage regulation on the feeder under consideration are given in graphic form in Fig. 5, curve 0-6. These curves are plotted to the same scale as Fig. 4, so that direct comparison can be made.

**Case 7. Losses in a feeder employing the usual method of voltage regulation.** In order to provide 2300 volts at the receiving end of the feeder under consideration, the voltage at full load at the sending end, that is, the primary voltage of the feeder transformer, must be raised 16.5%.

The losses for all loads are plotted in Fig. 5, curve 0-7. Note the greater losses as compared to curve 0-6.

From this discussion, it may be seen that automatic power factor correction has considerable possibilities when applied to distribution feeders. It is felt that in the near future the savings to be gained in equipment and power will cause this form of regulation to be common practice.



# COOLING MERCURY ARC RECTIFIERS

• H. O. Winograd
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The flow of current through a rectifier is accompanied by a drop in voltage between the anodes and the cathode called the "arc drop." The product of this voltage and current represents a power loss in the rectifier. This loss is converted into heat and must be removed to keep the temperature of the rectifier within a safe operating range.

Rectifiers of low current capacity can be self cooled by natural convection of air or can be cooled by a fan. However, these cooling methods are inadequate for rectifiers of larger capacity having a high ratio of power loss to surface area. Such rectifiers, which are used as power converters for railway, chemical, and industrial services, and are of the steel-enclosed type, are cooled by circulation of water through jackets surrounding the rectifier casing.

A cross-section view of a rectifier of this type is shown in Fig. 1. The cathode plate, tank, anode plate, and dome are water-jacketed. The cooling water enters the cathode jacket, flows through the other jackets as indicated in Fig. 1, and is discharged at the top of the condensing dome jacket. Since the cathode plate is insulated from the tank, a pipe of insulating material (rubber hose) is used to connect their jackets. The voltage between tank and cathode being small, approximately ten to 15 volts, a relatively short hose is required to limit the current flowing through the water to a harmless value.

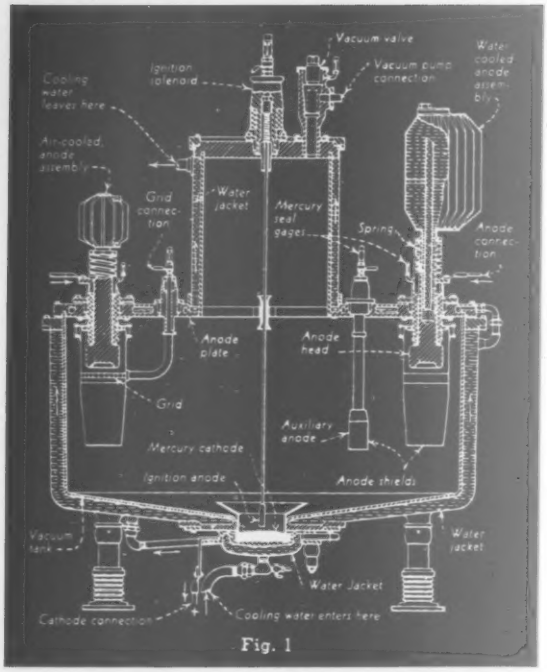


Fig. 1

The anodes are provided with individual radiators which may be of the solid fin or water-filled type, depending on the current rating of the anode. These radiators are self-cooled by air convection and have no connection with the water cooling circuit of the tank. They serve to maintain within safe limits the temperature of the anode shaft and the vacuum seal between the shaft and anode insulator.

To provide additional cooling surface, some rectifiers are equipped with cooling coils extending into the rectifier tank (see figure on p. 25).

The arc drop, which represents the power loss in the rectifier, consists of three portions: 1. The voltage drop at the anode surface; 2. the voltage drop in the arc between anodes and cathode; 3. the voltage drop at the cathode.

The power loss at the anodes constitutes approximately 25 per cent of the total loss. Part of the heat produced by this loss is conducted through the anode shaft and is dissipated by the anode radiators. The rest is transmitted by radiation and conduction to the anode shields and insulators, which in turn transmit it by radiation to the water-jacketed surfaces of the tank.

The power loss in the arc forms approximately 35 per cent of the total loss and is transmitted to the tank surfaces almost entirely by radiation, either directly or through the anode shields as intermediate radiators.

The power loss at the cathode is approximately 40 per cent of the total loss. Part of this loss is conducted through the mercury to the water-jacketed cathode plate; the remaining part is carried off largely through evaporation of mercury, which recondenses on the surfaces of the tank, giving up its heat of vaporization.

With the exception of the heat transmitted to the anode radiators, all the heat generated in the rectifier is transmitted to the water-jacketed surfaces of the cylinder. As the operating temperature of the rectifier (50° C. to 60° C.) is higher than the ambient temperature, part of that heat is dissipated to the surrounding air. About ten to 15 per cent of the total heat is thus dissipated from the surfaces of the tank and anode radiators, the amount depending on the relation between the total losses and the surface area, the operating temperature of the rectifier, and the ambient temperature. The rest of the heat is carried off by the cooling water.

The operating temperature of a rectifier has considerable influence on its operating characteristics, as it affects the flow and density of mercury vapor. If the temperature is too high, the resulting high mercury vapor pressure may cause frequent failures of the valve action of the rectifier. Excessive vapor pressure may also result in increased arc drop. If the temperature is too low, there is insufficient mercury vapor for ionization of the arc path, causing an increase of the arc drop. A shortage of mercury vapor at excessively low temperatures may also produce voltage surges in the anode circuits, which are likely to cause disturbances. The effect of temperature on the operation is more pronounced at high currents.

It has been found from tests and experience that the best operating temperature range of rectifiers, as measured at the anode plate, is between 50 and 60° C. Rectifiers for high d-c voltage service, such as used for supplying power to radio transmitters, have to be operated at lower temperatures in order to maintain a lower mercury vapor pressure.

The cooling system of a rectifier has to fulfill the following requirements:

It must carry off the rectifier losses.

It should maintain the rectifier temperature within the range required for efficient and reliable operation.

It should minimize the corrosive effect of the cooling water at the surfaces of the rectifier tank and jackets.

In the selection and design of a cooling system, the first cost of the cooling equipment, the space requirements, and the operating cost also have to be considered.

## • Rectifier cooling systems

Rectifier cooling systems may be divided into three general classes:

The direct cooling system, in which the water from the source of the water supply is admitted directly into the rectifier jackets.

**The indirect cooling system with water-to-water heat exchanger**, in which the water is recirculated in a closed circuit between the rectifier and the shell of a water-to-water heat exchanger, where the heat is transferred to the cooling water flowing through the tubes of the heat exchanger.

**The indirect cooling system with water-to-air heat exchanger**, in which the water is recirculated in a closed circuit between the rectifier and a fin-type radiator, where it is cooled by forced draft from a fan or blower.

These cooling systems are described below.

## • Direct cooling system

In Fig. 2 is shown one type of direct cooling system. The cooling water from the water supply line flows through the rectifier jackets and is discharged to the drain. Since the cathode is the positive terminal of the rectifier unit, and the rectifier tank is at practically the same potential as the cathode, a pipe of insulating material is used to connect the rectifier cooling circuit to the grounded water supply to prevent grounding of the positive pole.

In many installations using rectifiers, the negative pole of the d-c system is grounded, as for example in railway service, or a floating ground is maintained intermediate between the positive and negative poles, as in chemical plants. In such installations the insulating pipe must be sufficiently long to limit the leakage current flowing between the tank and ground through the water to a small value. This leakage current causes electrolysis of the water, liberating hydrogen at the grounded (negative) end of the insulated water connection and oxygen at the cathode (positive) end. The oxygen thus liberated is carried along by the water and may cause corrosion of the tank. To minimize its corrosive effect, the leakage current should preferably be limited to less than 6 milliamperes. On the discharge side, the rectifier may be insulated from ground through an open stream of water or the discharge pipe may be made of insulating material. The leakage current flowing through the discharge stream is less harmful to the rectifier, since the oxygen is carried away by the water and its corrosive effect is generally limited to the terminal fitting of the discharge pipe.

The flow of the cooling water is regulated by means of a thermostatically operated regulating valve, the actuating bulb of which is shown located in the drain pipe. This valve serves to maintain the rectifier temperature approximately constant.

In Fig. 3 is shown another type of direct cooling system. The cooling water is circulated between the rectifier and a water tank by means of a motor-driven water pump. Cold water from the supply line is admitted into the circuit at the suction side of the pump and mixes with the hot water from the tank before entering the cathode jacket. The admission of cold water is regulated by means of a temperature control valve, actuated by a thermostat in the rectifier discharge line. The excess water is discharged to the drain through an overflow pipe of the water tank. The water level in the water tank is maintained above the highest water level in the rest of the cooling circuit to keep the system primed. The discharge water from the rectifier enters the tank below the overflow level in order to avoid excessive agitation which would cause absorption of air.

All the equipment enclosed by the dot-and-dash line, including the water tank, circulating pump and temperature control valve, is maintained at approximately the same potential as the rectifier and is insulated from ground. Short insulating pipes H2 and H3 insulate the rectifier tank from the cathode and also serve to prevent flow of power current in case of an accidental ground on the other equipment of the cooling circuit in installations having the negative pole of the d-c system grounded.

The cooling system of the rectifier is connected to the grounded water supply over the insulated water pipe H1 which is sufficiently long to keep the leakage current through the water within safe limits.

## • Indirect cooling system with water-to-water heat exchanger

This type of cooling system, shown in Fig. 4, is the one most commonly used. The water-to-water heat exchanger consists of a bundle of tubes connected in parallel between two headers and en-

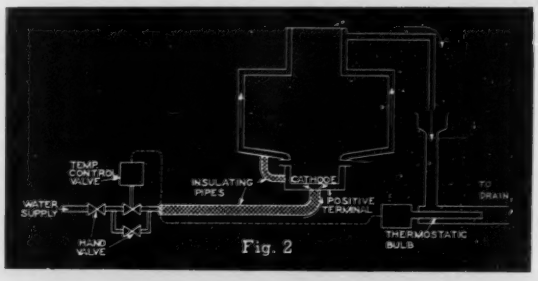


Fig. 2

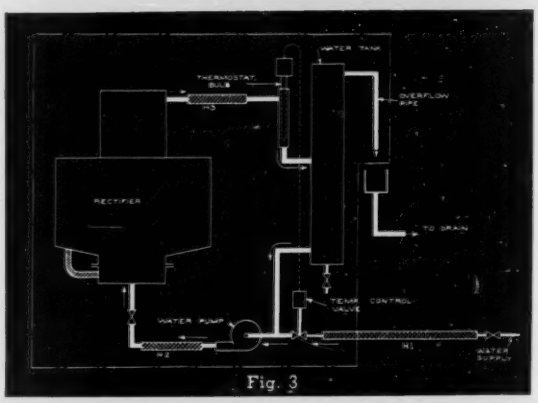


Fig. 3

cased in a cylindrical shell. The raw (cold) water flows through the tubes between the headers; the soft (hot) water flows through the shell, and its flow is directed across the tubes by a series of baffle plates surrounding the tube bundle.

The cooling water is recirculated in a closed system between the rectifier and the shell of the heat exchanger by means of a motor-driven water pump. This water circuit is indicated in Fig. 4 by heavy lines. The cold water from the water supply line flows through the tubes of the heat exchanger and is discharged to the drain. The heat is transferred from the hot water to the cold water through the walls of the tubes. The heat exchanger is connected for counterflow direction of water flow in the two circuits in order to obtain higher heat transfer efficiency. The flow of cold water is regulated by means of a temperature regulating valve which is actuated by a thermostat located in the water piping on the intake side of the water pump. The thermostat and valve serve to maintain the temperature of the rectifier water approximately constant.

If the rectifier is provided with a cooling coil, it is preferable to connect the coil circuit in parallel with the cooling circuit of the rectifier tank, as shown in Fig. 4. If the two circuits were connected in series, the resistance to the water flow would be increased considerably, so that a water pump for a higher pressure would be required with the consequent risk of developing water leaks due to the higher pressure.

The cooling system is provided with an expansion tank, which is mounted above the rectifier and is provided with an overflow pipe and a water level gauge. The purpose of the expansion tank is to keep the cooling system full and prevent access of air into the circuit. It acts as a reservoir to permit expansion of the water as a result of changes in temperature, and to make up for loss of water through possible leakage at the packing glands of the water pump and valve stems.

The equipment and piping shown enclosed by the dot-and-dash line in Fig. 4 are at approximately the same potential as the rectifier, and are insulated from ground. The rectifier is connected to the cooling equipment through short insulating pipes H2, H3, and H4, which provide insulation between the tank and cathode and prevent flow of power current in case of an accidental ground on the cooling equipment. The heat exchanger is connected to the cold water supply over the insulating pipe H1, which is sufficiently long to limit the leakage current to ground to a harmless value. The discharge pipe of the heat exchanger is provided with a pipe of insulating material H5 to increase the resistance of the water stream to the grounded drain funnel.

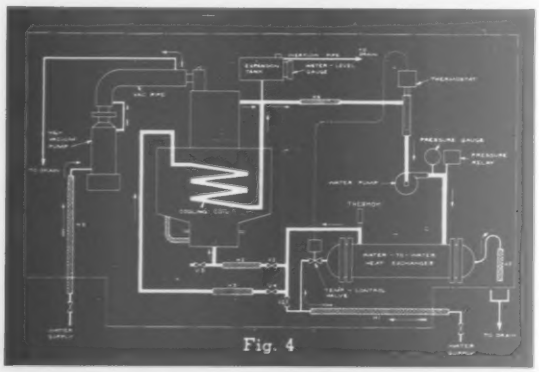


Fig. 4

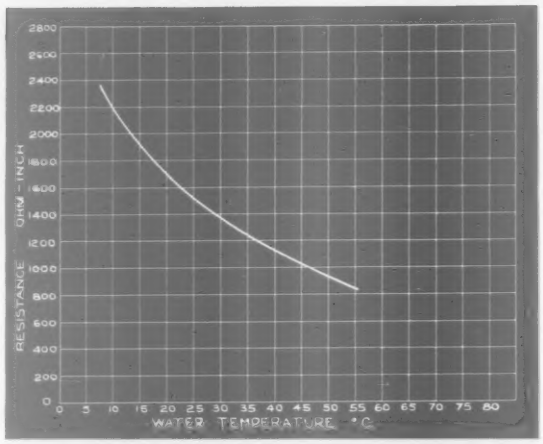



Fig. 5 — Resistance of Water as a Function of Temperature

Hand valves V3 and V4 are used to adjust the flow of water through the rectifier and cooling coil. Valve V2 is used for filling the rectifier cooling system and is normally closed. V5 is a drain valve, normally closed. The pressure relay serves to give indication and provide protection for the rectifier in case the pump should stop while the rectifier is in operation.

To the left of Fig. 4 is shown the cooling circuit of the high vacuum pump which will be described later.

The purpose of insulating the cooling equipment from ground and maintaining it at approximately the same potential as the rectifier can be explained with the aid of the curve in Fig. 5, which shows the relation between the temperature of water and its resistivity. As can be seen from this curve, the resistivity of water at 55° C., which can be taken as the temperature of the water circulating through the rectifier, is approximately one-half the resistivity at 20° C. Addition of corrosion protective chemicals to the water greatly decreases its resistivity. For example, a 0.5 per cent solution of sodium dichromate in water decreases its resistivity to about one-thirtieth of its original value. If the heat exchanger were grounded, and assuming that the negative pole of the d-c system were also grounded, the connections H2, H3, H4 (Fig. 4) would constitute three parallel circuits for the flow of leakage

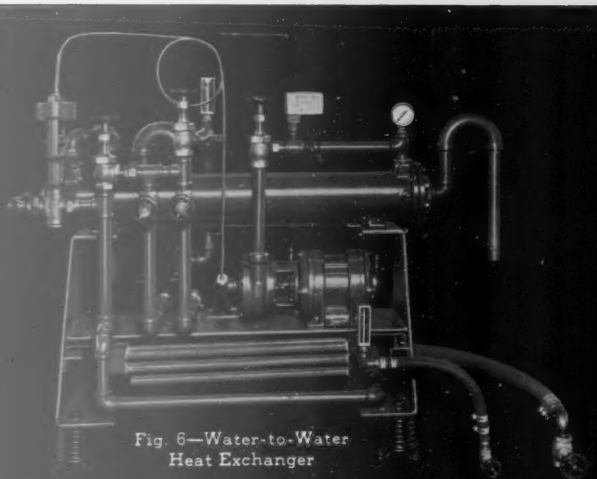


Fig. 6—Water-to-Water Heat Exchanger

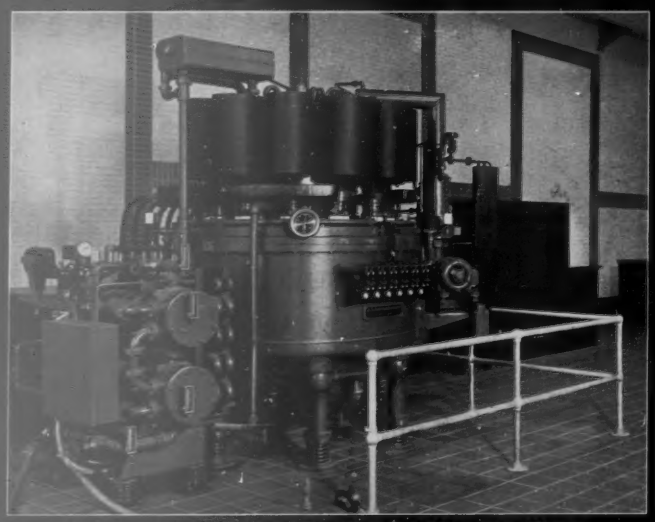


Fig. 7—600 Volt Railway Rectifier with Water-to-Water Heat Exchanger

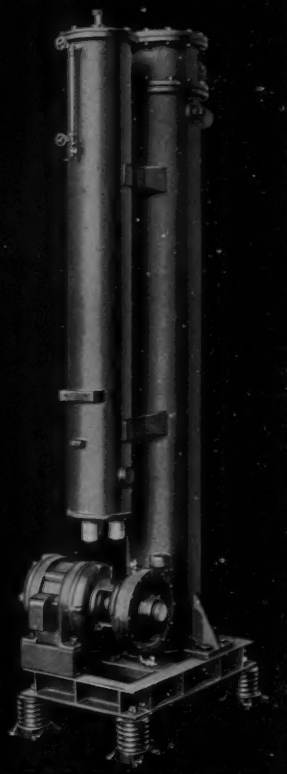


Fig. 8—Vertical Water-to-Water Heat Exchanger

current from the rectifier to ground. To provide sufficient resistance to limit the leakage current to a reasonable value, these connections would have to be quite long, which would complicate the installation and would necessitate using a larger pump to overcome the pressure drop in these connections. By insulating the heat exchanger from ground as shown in Fig. 4 the leakage current is made to flow through untreated water of lower temperature, so that the insulating connections to ground (H1, H5) can be of reasonable length.

In Fig. 6 is shown an assembly of a water-to-water heat exchanger with the water pump, piping, valves, and other equipment shown in the diagram of Fig. 4. The insulating pipes H1 and H6 are located at the lower part of the assembly. Heaters are shown in the water piping of the rectifier circuit. These are intended for use during the bake-out of the rectifier.

In Fig. 7 is shown a rectifier installation with the cooling equipment alongside the rectifier.

In Fig. 8 is shown another assembly of a heat exchanger, which is mounted vertically and supports the expansion tank. The heaters are inserted at the bottom of the tank.

As can be seen in Fig. 6, the water pump is supported on the frame of the driving motor. Since the

frame of the motor is thereby put at the potential of the rectifier, while its winding is connected to the station auxiliary a-c supply, the motor winding is insulated from the frame for a higher voltage insulation class making it unnecessary to use an insulating transformer.

## • Cooling system with water-to-air heat exchanger

In Fig. 9 is shown a cooling system for rectifiers using a water-to-air heat exchanger. The water is circulated between the rectifier and a radiator, which consists of a series of parallel tubes connected between headers and provided with fins over their outside surfaces. The water flows through the tubes and is cooled by a forced draft of air blown over the tube surfaces by a motor-driven fan or blower.

The water temperature can be controlled by starting and stopping the blower, by varying the speed of the motor, or by adjusting the opening of the louvers to regulate the flow of air, as shown in Fig. 9. To avoid using a variable speed motor, the first and last of the above-mentioned methods are generally used.

The entire cooling system is insulated from ground. The blower and its driving motor can be placed at ground potential by insulating the radiator from the blower casing. The cooling system can be filled through an opening in the expansion tank or through the rectifier drain valve by making a temporary connection to a water supply.

In Fig. 10 is shown an assembly of a fan-cooled water-to-air heat exchanger unit with the expansion tank mounted above the radiator.

In Fig. 11 is shown a cooling system for rectifiers using both water-to-water and water-to-air heat exchangers. The rectifier water flows through the two heat exchangers in series. The water-to-air cooler is placed first in the circuit, so that it can receive the water at a higher temperature. Since the temperature difference between the air and water is usually relatively small, the capacity of the cooler can be increased appreciably by increasing the temperature differential by a few degrees.

The transfer of heat between the rectifier water and the cooling medium in the two heat exchangers is controlled by means of individual thermostats in the same manner as in the cooling systems shown in Figs. 4 and 9. When two heat exchangers are used as shown in Fig. 11, one of the heat exchangers is generally designed to provide sufficient cooling capacity for average normal operating conditions, and is considered the leading cooler, while the other is used to provide additional cooling capacity for abnormal conditions. The thermostat controlling the operation of the leading cooler should be set lower than the other thermostat. In other respects the operation of this cooling system is similar to that of Figs. 4 and 9.

## • General

In the cooling systems shown in Figs. 4, 9, and 11, the rate of water circulation through the rectifier is adjusted by means of the hand valves in the circuits and remains unchanged under all conditions of load. These cooling systems are generally designed for such a rate of water flow that at the highest sustained current rating of the rectifier the temperature rise of the water in passing through the rectifier would be approximately eight to 12° C.

To obtain an idea of the heat dissipated by the rectifier cooling system and of the rate of water circulation involved, an example will be given of a rectifier rated at 5000 amperes with an arc drop of 27 volts at rated current. The total loss in the rectifier is 135 kw. Allowing about 12 per cent for heat dissipated by the external surfaces to the ambient air, the net loss to be carried off by the cooling system would be approximately 119 kw or 405,000 B. T. U. per hour. Allowing for a 10° C. temperature rise in the water flowing through the rectifier, 45 gpm of water would have to be circulated. If the discharge temperature of the water is kept at about 55° C. the inlet temperature would be about 45° C.

## • Factors to consider in selecting a cooling system

The relative merits of the several types of cooling systems previously described and the factors considered in the selection of a cooling system will now be discussed.

The cooling system shown in Fig. 2 is the simplest and at one time was used generally. However, its shortcomings became more apparent as rectifiers of higher current capacity were developed and as more experience was gained with the operation of rectifiers. One objection to this system is that it is difficult to maintain the rectifier within the optimum range of temperatures under variable load conditions; also the low temperature of the incoming water may have a detrimental effect on the operation of the rectifier. Another objection is the corrosive action of the water on the tank sur-

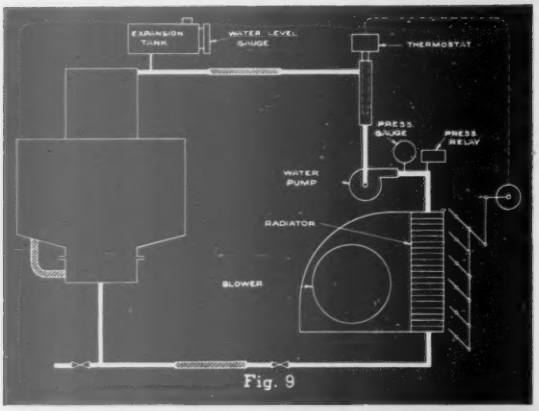


Fig. 9

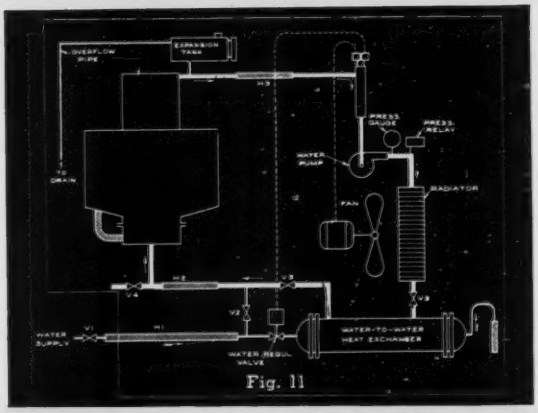


Fig. 11

faces, which may cause pitting. Water coming from rivers, lakes, or reservoirs contains large quantities of dissolved oxygen, which is liberated as the water is heated up in passing through the rectifier jackets and has a tendency to adhere to the tank surfaces in the form of bubbles owing to the slow rate of water flow. This was found to be a major cause of corrosion. Since there is a continuous flow of new water, it is not very practicable to treat it chemically, and periodic painting of the tank surfaces was found to be only a partial remedy.

Fig. 10 — Water-to-Air Heat Exchanger Unit for a 600 kw, 575 Volt Rectifier

With the cooling system of Fig. 3 the temperature of the rectifier can be controlled much more accurately. Since water is continuously circulated through the rectifier, the admission of cold water may be stopped completely by the temperature regulating valve during periods of light load, without any risk of developing local hot spots which may form steam pockets, as would be the case with the circuit of Fig. 2. The higher rate of water flow possible with the system of Fig. 3 would result in more uniform temperatures between the inlet and discharge sides of the rectifier; it would also reduce the tendency for accumulation of oxygen bubbles on the surfaces of the tank. However, since the water is continually being renewed by admission of fresh water, it is not feasible to treat the water chemically and the risk of corrosion is not eliminated.

Incidentally, the cooling system of Fig. 3 is the most economical in regard to consumption of water, because the temperature of the water discharged to the drain is at all times practically the same as the normal temperature of the water on the discharge side of the rectifier, as no fresh water is admitted until normal temperature is reached.

The cooling system shown in Fig. 4 has the same advantages as that of Fig. 3 in regard to temperature control. However, it provides better protection against corrosion of the rectifier tank. Since the same water is recirculated continually, with only infrequent additions of small quantities to make up for loss due to leakage, it becomes de-aerated so that the corrosive effect of oxygen dissolved in the water is practically eliminated. It is also possible to add chemicals to the water to protect the metal against corrosion. Sodium dichromate (about 0.5 per cent solution) has been used effectively for treating water in rectifier cooling systems. Sodium dichromate is a strong oxidizer. It forms on the surface of the metal a dense film consisting of iron and chrome oxides, which protects the metal against further corrosion.

The use of the heat exchanger increases somewhat the cost of the cooling equipment. The consumption of raw water is also greater than with the cooling system of Fig. 3, since the temperature of the water which is flowing through the tubes of the heat exchanger and is discharged to the drain must be lower than the temperature of the rectifier water to permit heat transfer. However, the protection against corrosion possible with this system is considered to be of sufficient importance to overbalance the above-mentioned disadvantages. As was stated previously the cooling system with water-to-water heat exchanger is now the most generally used system.

The cooling system of Fig. 9 has the same advantages as that of Fig. 4 in regard to temperature

control and protection against corrosion. However, a large radiator and blower are required to provide sufficient cooling capacity, on account of the relatively small difference between the temperatures of the air and water, taking into account the highest ambient summer temperature.

The cost of a forced draft cooler is appreciably higher than a water-to-water heat exchanger. It occupies more space and provision must be made for intake and discharge of cooling air. The noise of the blower and fan may also be objectionable. The cost of power required for the blower motor in most cases exceeds the cost of water consumed in a water-to-water heat exchanger. This cooling system is generally used only when a dependable supply of cooling water is not available.

The objectionable features of the forced draft cooler may be offset partly by the combination shown in Fig. 11. The forced draft cooler used in this cooling system can be designed for average load and air temperature conditions. Its size and cost could therefore be reduced. For higher loads and air temperatures, supplementary cooling would be provided by the water-to-water heat exchanger.

## • Temperature controllers

Two types of temperature controllers have been used for regulating the flow of cooling water. One type, shown in Fig. 6, consists of a thermostatic bulb filled with a vaporizable liquid and a valve directly actuated by it. The pressure developed by vaporization of the liquid under the influence of temperature is transmitted through a liquid in a flexible tube to metal bellows which moves the valve stem against the countertorque of a spring. The controller is designed to make the valve move from the full-closed to the full-open positions in response to a temperature rise of only a few degrees above the setting. The operating temperature is set by adjusting the spring compression.

The other type of temperature controller used for rectifier cooling circuits is electrically operated. It consists of a thermostat and a motor-operated valve controlled by it. The action of the thermostat is modulated electrically by means of a coil which is connected in series with a small rheostat operated by the valve motor. Through this modulation, the valve motor can take definite, stable, positions between the full-open and full-closed positions, depending on the temperature setting, within a range of a few degrees. The electrical type of controller is more positive than the direct-acting type on account of the higher operating torque of the motor. Scale or rust sometimes causes sticking of valves of the direct-acting type if hard or impure water is used.

The electrical temperature controller described here can also be used for controlling the louvers of a forced-draft cooler, shown in Fig. 9.

## • Insulating water connections

The insulating pipes used in the cooling circuits of rectifiers can be made of ceramic material, bakelite or rubber. Rubber hose, although subject to deterioration with age, is in general more serviceable as it can be installed more easily and is not subject to breakage. A good grade of rubber hose can last for a number of years.

## • Cooling of high vacuum pump

The high vacuum pump, used for maintaining the high vacuum required in a rectifier, operates by a continuous cycle of vaporization and condensation of mercury. The mercury is vaporized by means of an electric heater attached to the bottom of the pump, and is recondensed by water flowing through water jackets surrounding the body of the pump. The pipe connecting the high vacuum pump to the rectifier is also water-jacketed and cooled to prevent transfer of mercury between the pump and the rectifier.

The cooling circuit of the high vacuum pump and the pipe is shown in Fig. 4. Water, from the water supply line, flows in series through the insulating pipe H6, the water jackets of the pump and the vacuum pipe, to the drain. The cooling circuit of the pump is independent of the rectifier cooling system. For efficient operation and to prevent transfer of mercury vapor to the rotary vacuum pump, the cooling water temperature of the pump should be kept below 40° C. For this reason it is usually not desirable to combine the cooling circuit of the pump with that of the rectifier. Another reason is that it is general practice to keep the pump in continuous service even when the rectifier is not carrying load, in order to avoid the delay of ten to 15 minutes required to bring the pump mercury to operating temperature.

The pump heater is rated at 1000 watts or less, depending on the pumping speed required. The water consumption is therefore quite small—about one-third gallon per minute. The pump can also be cooled by a closed recirculating cooling system using a water-to-water heat exchanger, and in installations having no dependable water supply a water-to-air heat exchanger can be used.

The pump can be protected against failure of the cooling system by means of a dipper switch on the discharge side or by means of a thermostat in the water jacket.

# ENGINEERING FUNDAMENTALS

## RELATION OF COST TO RPM IN ROTATING MACHINES

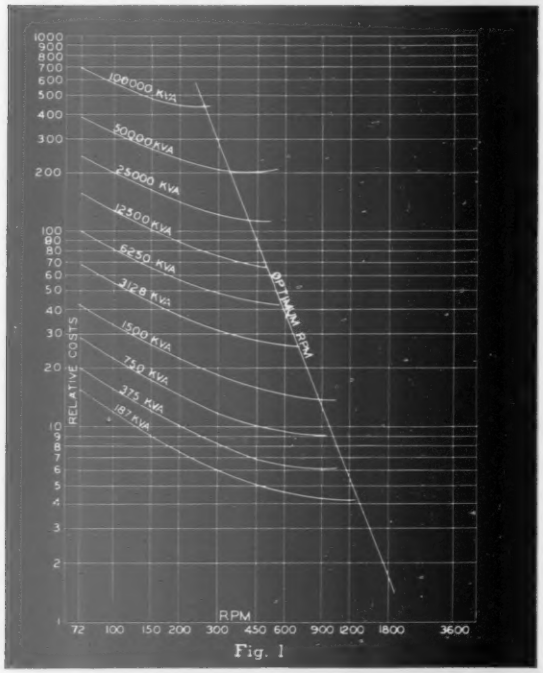



Fig. 1

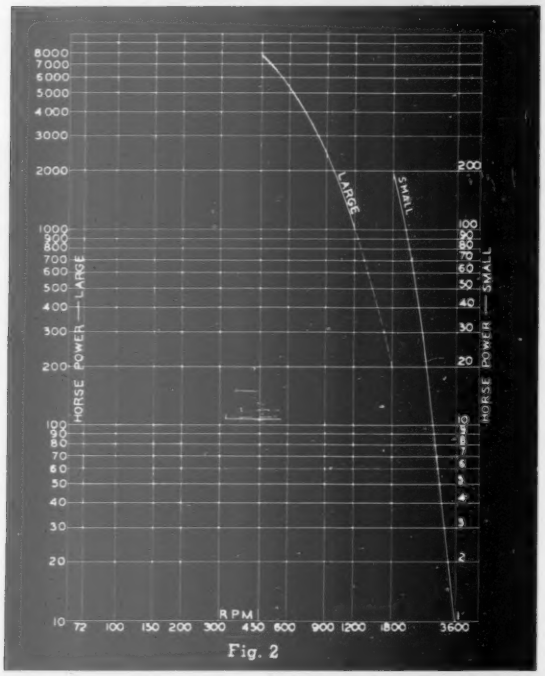



Fig. 2

There is a general feeling that "the higher the speed the cheaper the electric generator or motor." This is true, however, only up to a certain point.

At any particular time the designer is limited largely by the physical characteristics of materials available for use in his design. Fig. 1 gives the relative costs of water wheel generators at various speeds for a number of capacities. For comparison they have naturally been reduced to similar characteristics.

It will be seen that for any given capacity the cost decreases only to a minimum point beyond which the use of special higher cost material may permit a little higher speed, at increased cost of course, or it may become necessary to subdivide the machine into two parts if the speed is fixed.

In other words the curve drawn through the minimum cost points of the various ratings shows the present-day speed giving minimum costs for any particular rating. Fig. 2 gives the optimum speed for 60 cycle a-c motors. It is evident in both cases that the synchronous speed right on the curve or the first synchronous speed below the curve is the one to be selected.

On Fig. 2, therefore, 1200 rpm is the best speed from 1000 hp down to almost 200 hp and 1800 rpm from 200 down to fractional hp machines.

For direct current motors Fig. 2 also applies approximately. Here, however, there is no frequency limitation and except for the fact that 60 cycle speeds practically dominate today, the curve can be followed.

It is to be borne in mind that Fig. 1 applies to water wheel generators, which must stand 85 to 100 per cent overspeeds. Sixty cycle synchronous condensers, which are set to trip out at 25 per cent overspeed, therefore have an optimum speed approximately 50 per cent higher.

An interesting commentary on the limitation of design by available materials is indicated by the fact that about 30 years ago it was considered impossible to build a larger steam turbine at 3600 rpm than 500 kw, because the blades could not be made long enough to permit more steam to pass through. A 50,000 kw at 3600 is today possible.

# MOTORS AND DRIVES IN COTTON MILLS

• Harry S. Roberts
ALLIS-CHALMERS MFG. CO. . . . ATLANTA OFFICE

The past few years have shown marked improvements in the application of motors to textile machinery and in the drives that are installed to transmit power from these motors to line shafts, or machines, as the case may be.

The first alternating current motors to be installed in a cotton mill were placed in service nearly 50 years ago. At that time only motors of 100 hp and larger were used. This made a more flexible arrangement than could be obtained with mechanical drive from a steam engine but did not give the improvement in speeds that were later obtained by the use of smaller motors, with fewer machines per motor or a motor to each machine. When the smaller motors were installed not so many belts were interposed between the motors and the driven machines, resulting in better speeds and less machines stopping in the event of a motor failure.

It is only in recent years that the textile machinery manufacturers have made any appreciable change in their product, resulting in improvements which make necessary a careful study of each motor and drive application, not only as to capacity, but as to the suitability of each to operate in its designated location.

For the benefit of those who are not familiar with the machinery used in the manufacture of cotton goods a brief description of each process is given, starting with raw cotton in the bale and ending with cloth ready for shipment to the finishers.

## • Opener room

Before the ties and bagging are removed from a bale of cotton, the cotton is in a compressed condition. The machinery in an opener room thoroughly opens, cleans, and aerates this compressed cotton, after which it is blown through a metal duct to the picker room.

The machinery in an opener room consists of lattice-feed aprons, automatic feeders, bale breakers, "centrif-air" machines and a fan to blow the cotton to the picker room.

To insure a uniform mix or blending of the cotton some eight or ten bales are placed adjacent to each lattice-feed apron, a layer from each bale being placed on the feed apron. As these layers progress through the machines mentioned above, the fibers from each bale are mixed with the others. Should one bale have a staple that is slightly off standard, this mixing would so distribute the fibers from it that the variation would not be evident further along in the process of manufacture.

As the power requirements of the machines in the opener room are small, it is usually customary to drive them in groups from a line shaft, with a multiple V-belt drive transmitting the power from the motor to the shaft. The fans are as a rule driven by a separate motor with a multiple V-belt drive.

## • Picker room

Cotton from the opener room is discharged onto a conveyor, which delivers it to the automatic feeders that supply the pickers. As the cotton passes through the pickers it receives a thorough beating, which removes any foreign matter, and also fluffs and aerates it. After this process the cotton is delivered from the finisher end in a roll, about 40 inches wide, called a lap.

Until rather recently there were three processes of picking: i. e., breaker pickers, intermediate pickers, and finisher lappers. After passing through the breaker picker the cotton was formed into a lap, which had to be removed by hand and placed on the receiving end of the intermediate picker. The same operation was necessary after it had gone through the intermediate, the lap being transferred to the finisher lapper by hand.

New pickers that are installed today are known as one-process pickers, the cotton being worked through two or three beaters, as the case may be, without any handling, resulting in a saving in labor and giving a more uniform lap.

With rare exceptions pickers are driven by individual motors, one to each beater. In most cases each motor is mounted on an "A" frame of the type shown in Fig. 1. In this case a flat belt is used to transmit the power, although multiple V-belt drives have generally proved more satisfactory for this service, as the starting duty is rather severe and the flat belts have a tendency to run off the pulleys.

A simple, inexpensive installation that will operate with a minimum maintenance cost, and permit easy inspection, may be made by placing each

motor on a base mounted on the floor, the motor shaft being about the same elevation as the beater shaft, and with a multiple V-belt drive to transmit the power.

While the air in the opener and picker rooms does not have as much lint present as is found in some other departments, it is highly desirable to install motors that are either self-cleaning or are easily cleaned, for in these rooms the motors used are small, and if of a conventional type tend to choke up quickly.

Fires caused by pieces of metal, or by bale buckles in the cotton being struck by moving parts of the machines, often occur in these departments. When those fires start the sprinklers deluge the rooms with water. For this reason motors in these two departments should be sealed against moisture. Either "Seal Clad"* or self cleaning motors will better fill these requirements than any others that are now available.

## • Cards

The laps from the finisher pickers are delivered to the cards, one lap to a card. The carding process removes any remaining dirt or foreign materials and short unspinnable fibers, and straightens the remaining fibers so that they lie practically parallel to each other. The carded cotton is delivered in a gossamer-like sheet, called sliver, which, after passing through a trumpet and coiler, emerges as a loosely laid cotton rope without twist, and is then coiled in a roving can for convenient handling to the next process, which is "drawing."

Individual motor drive for cards has not been successful because the very high starting torque and low speed required result in a motor that cannot be built with satisfactory efficiency and power factor characteristics.

The most satisfactory arrangement yet found for driving cards has been to arrange cards in fairly small groups with one line of shafting driving two lines of cards. Each shaft is driven through a multiple V-belt drive by a ceiling-mounted motor as shown in Fig. 2. With an installation like this, the costs of maintaining the drives are very low. As no lubrication of the drives is required there is no danger of oil dropping onto the roving and causing seconds. Inspection is simple, as a glance at any one of the drives shown reveals the need for new V-belts or their tightening.

## • Drawing

From four to six cans of card sliver or roving are placed behind each delivery of drawing, there being usually six deliveries per frame. As the sliver is worked through the drawing frame the fibers are straightened and the resultant sliver, obtained by combining six ends into one, is more uniform in size and weight than each of the original ends were.

Group drives, two- and four-frame drives, and individual drives are used to drive drawing frames.

The group drive, where one ceiling-mounted motor through belting and shafting drives a number of drawing frames, is not often applied in new installations.

Two- or four-frame drives with ceiling-mounted single- or double-extended shaft motors are used quite extensively, but because of the slow speed of the driven shafts, 600 or 720 rpm motors are required for satisfactory results. The cost of these slow speed motors with motor supports, belting, and control equals or in some cases exceeds the cost of individual drives.

Only since the development of the multiple V-belt drive have individual drives on drawing been practical. Multiple V-belt drives permit the use of 900 or 1200 rpm motors, so that combined cost of the motors, drives, and control will not exceed, and in many cases not equal, the cost of two- or four-frame drives. The individual motors are mounted on the floor, operating on short center distances, or as shown in Fig. 3, on a platform made of sheet steel mounted on the end of the frame. The arrangement shown takes up very little more space than the frame itself requires, and places the motor up off the floor where it is easily accessible and away from dirt.

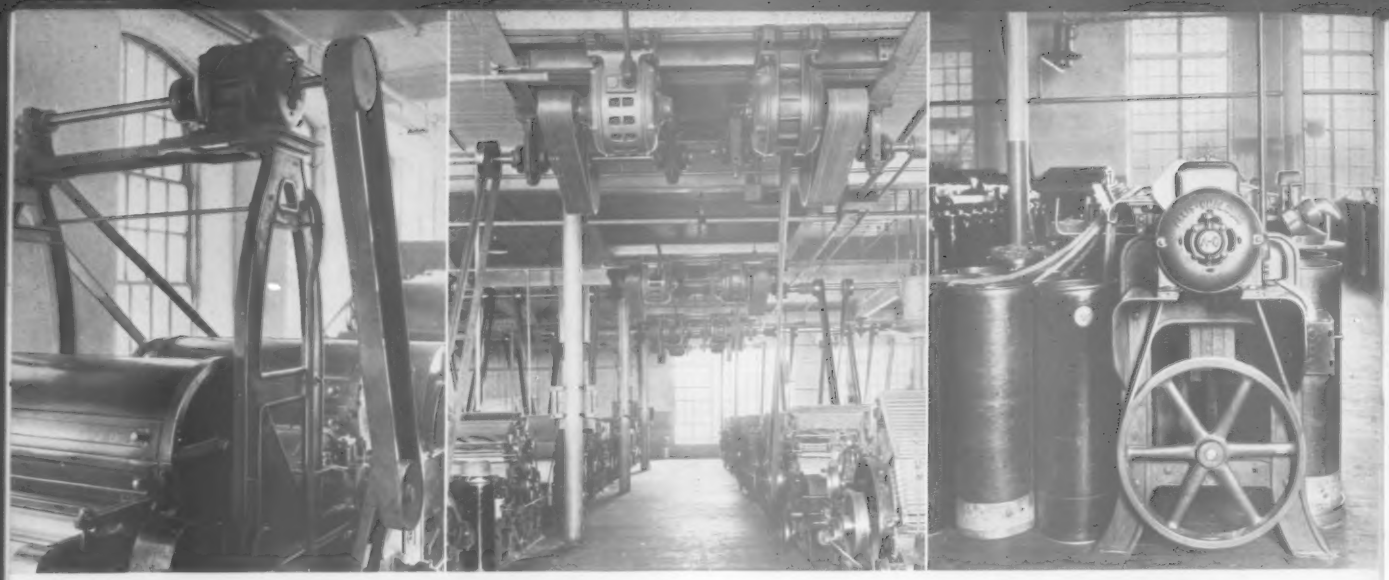
## • Slubbers, intermediates, and fine frames

Roving from the drawing frames, in cans, is delivered to the rear of the slubbers, one can for each spindle. The slubber reduces the diameter of the roving and puts the first twist into it. Roving from the slubbers, on bobbins, is delivered to the intermediates, where it is further reduced in size and more twist added. The same process is repeated on the fine frames, and the roving is ready to be delivered to the spinning frames. In modern practice, where long draft spinning frames are used, one of the above processes and in some cases two, depending on the size of yarn to be spun, would be eliminated.

Two- and four-frame motor drives for slubbers, intermediates, and fine frames give satisfactory results. The driven speeds are low, necessitating the use of 720 and 900 rpm motors if these types of drives are used. The motors, being ceiling-mounted, are not so easily serviced and unless "Seal Clad" motors are used the problem of keeping them clean is a serious one.

In starting any of the above mentioned roving frames it is necessary to have smooth acceleration, as a jerk will break down a number of ends. For this reason satisfactory installations of individual

* "Seal Clad" motors have their stator windings completely sealed and shielded by a bakelite moulded covering over the winding ends.



Left to Right. Typical operations in a large textile mill. Fig. 1 — Picker Motor Driving Beaters. Fig. 2 — Roller Bearing Ceiling-Mounted Motors Driving Cards. Fig. 3 — Motor with Multiple V-Belt Drive Mounted on Platform and Operating a Drawing Frame.

drives were not made until multiple V-belt drives were developed. As a result, these drives along with the self-cleaning motors have made possible installations, which give more constant speeds than formerly could be obtained with two- or four-frame motors. An installation of this type, driving intermediates, is shown in Fig. 4. The cost of maintenance of such an installation is practically negligible. With self-cleaning motors there is really no need of any cleaning, because any lint which enters the motor passes through and out to the room. Being equipped with ball bearings, the motors should not require greasing more than twice a year. The cost of maintaining the drives will not exceed eighty cents per machine per year.

## • Spinning

Roving from the fine frames is delivered to the spinning frames on bobbins, where it goes through nearly the same process as it went through on the fine frames, resulting in a yarn of the proper size and strength for the construction for which it is intended. If it is to be used for weaving, filling yarn goes direct to the looms, while warp yarn goes to the spoolers, warpers, slashers, and then to the looms.

A number of improvements made in spinning frames in the past few years have entirely changed the power requirements. Formerly a five horsepower motor was used to drive a filling frame and a seven and one-half horsepower motor a warp frame, but today a five horsepower motor is never used to drive a spinning frame and a seven and one-half horsepower motor is seldom used except for filling frames. Most of the motors used for this purpose are ten horsepower, with some 15 horsepower motors for heavy warp frames. This increase in power is accounted for by tape driving of the spindles, resulting in each spindle operating at a higher and more constant speed, producing more yarn per spindle.

While there are still a great many old installations of two- and four-frame motors driving spinning frames, all new installations are made with a motor driving each frame.

Individual motor drives for spinning frames are not new, the first complete installation having been made about 1911 or 1912. The motors used were equipped with waste-packed bearings, screens in the bearing heads to exclude lint, and tapered shafts with lockwashers and nuts. Mounted on the motor shafts were fiber pinions, which drove steel gears mounted on the cylinder shafts. This installation proved conclusively that individual drives resulted in at least five per cent more production than would have been obtained with four-frame drives. This increase was accounted for by the fact that the individually driven frames were all operating at the same speed, whereas there would be an appreciable variation in speeds on the frames driven by four-frame motors. This variation was caused by lint on the surface of the belts, causing a loss in speed until the belts were cleaned.

For a number of reasons the drives described were not satisfactory. The gears were removed and replaced by short center, silent chain drives. These chain drives were much quieter than the gears and for many years were the accepted standard, when individual motors were applied to either spinning frames or twisters.

Although the chain drives insured constant speed there were many objectionable features which prevented the individual drive from becoming universally accepted. The chain drives required lubrication. Invariably the chain cases leaked, resulting in a puddle of oil on the floor, which frequently spread to the aisle, making a hazardous passageway for employees. Another serious objection to the chain drives was in starting. When the switch was thrown on, the motor would come partly up

to speed before the chain could take the load, this resulting in such a severe jerk that cylinder heads were often broken.

The development of the multiple V-belt drive made available a means of transmitting power to spinning frames and twisters that left little to be desired. This drive is clean, flexible, easy to inspect and maintain. Other advantages are low maintenance cost, ability to produce smooth acceleration, and operation at constant speeds.

For mills that spin a wide range of numbers, necessitating considerable speed changing, the stationary controlled, variable pitch sheaves will save in the initial cost, save in man hours, as well as in frame hours. One overseer of spinning who has 43 ten horsepower self-cleaning motors and variable pitch drives reported that, with a helper, he changed the speed of these 43 frames in two hours, not quite three minutes to the frame. To have accomplished this by changing sheaves would have taken eight to ten times as long.

Despite the fact that some 25 or more years have elapsed since the first individual motors and drives were applied to spinning frames, not a single motor manufacturer had produced, up until two years ago, a satisfactory motor for this service. Those familiar with a cotton mill know that the spinning room is the worst, of all places in the mill, from a standpoint of lint in the air. While this lint is not noticeable upon casual inspection, it is everywhere, and it is often said that until an individual can walk through a spinning room without his nose itching it can be easily seen he hasn't been around a mill much.

Motors with screens over the openings in the end housings to exclude lint were unsatisfactory, because the screens plugged up and the motors ran hot—sometimes burning them out. Some manufacturers used a compound over the windings in an attempt to obtain a smooth surface so that lint could be dislodged when blown by compressed air. This scheme had some merit but the cleaning job still remained. These motors ran hot, and if one did burn out, the compound had to be removed before the rewinding could be made. Efforts were made by some motor manufacturers to produce a self-cleaning motor by taking a standard motor and modifying it so that the desired results could be obtained.

Finally, the self-cleaning motor was developed. Free, unobstructed air passages, with no projections, resulted in the prompt discharging of any lint entering the motor. Being clean, the temperature of the motor remains the same, year after year, the same as it was when the motor was first installed. Formerly, with the old style motors the hottest spots in the room were adjacent to the motors. These are now the coolest spots.

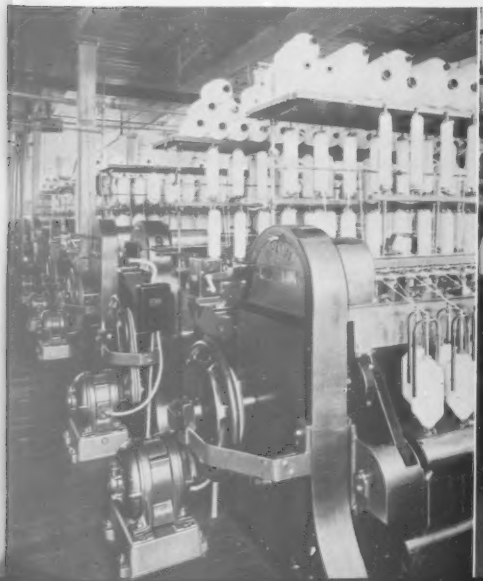
The starting characteristics of these motors are such that fewer ends will be down when starting up frames than with other motors offered for driving frames. This statement is substantiated by tests run by mill operators.

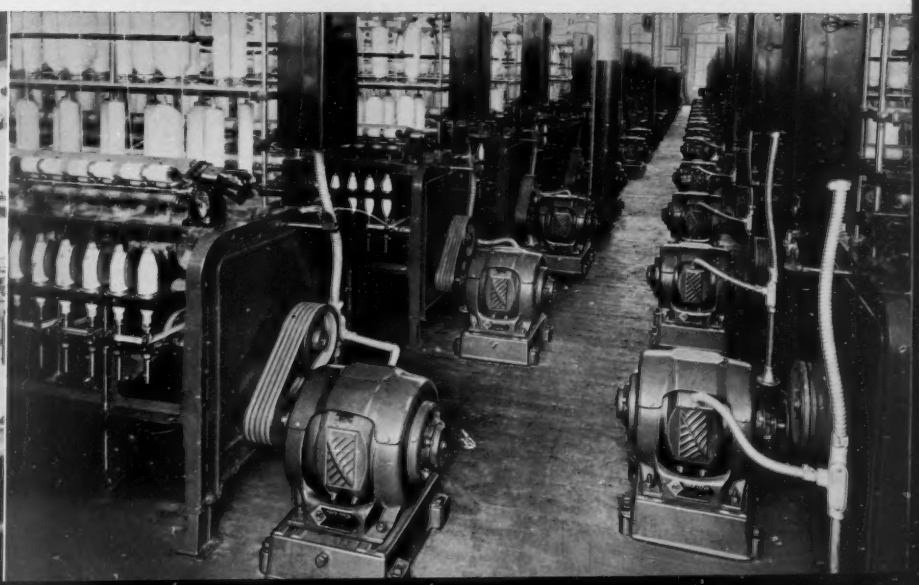
With ball bearings completely sealed, requiring lubrication not over four times a year, and in most cases two, these self-cleaning motors need practically no attention, giving better results than can be obtained with any other motors. Fig. 5 shows a part of an installation of 124 ten-horsepower self-cleaning motors and multiple V-belt drives.

## • Spoolers and warpers

Warp yarn from the spinning frames is delivered on bobbins to spoolers. Old style spoolers wound the yarn from the bobbins onto spools, the ends

Left to Right, Fig. 4 — Motors Using Multiple V-Belt Drives to Operate Intermediates. Fig. 5 — One Hundred and Twenty-four, Ten hp Self-Cleaning Motors and Short Center Multiple V-Belt Drives Driving Spinning Frames in a large, modern textile mill located in the South.





being tied by hand. Automatic spoolers wind the yarn onto packages called cheeses, the ends being automatically tied, the whole operation being performed in a much shorter time than on the old style spooler.

From the spoolers, the spools or cheeses are placed on a "V" shaped creel. Several hundred ends from the spools are wound on a wooden reel called a beam. After the beam is filled it is sent to the slasher room for final treatment before weaving.

Spoolers and warpers are usually driven with small individual motors and multiple V-belt drives.

## • Slasher room

The ends from four to six of the beams are run through a slasher, which impregnates the yarn with a sizing compound, drys the yarn, delivering the combined ends of the section beams onto one beam which goes to the looms. In the slasher room there are fans to exhaust the vapors, and size kettles for mixing the size and keeping it at the required temperature. Slashers are usually driven from a line shaft, one motor being used to drive them. Size kettles and fans are as a rule driven with individual motors.

## • Weaving

Before a warp on a loom runs out, and three or four feet of the ends are left, they are tied together behind the drop wires. On the cloth side of the loom a few inches of cloth are left. This leaves the ends of the old warp drawn through the drop wires, harnesses, and reeds. The ends of the new warp from the slashers are tied to the old ends by an automatic machine, which saves having to draw in each end through the drop wires, harnesses, and reeds. Warp yarn runs parallel to the selvage, filling yarn at right angles to it.

Looms that are installed today are almost without exception individually motor driven. There are several reasons for this. If looms are belt driven, the shafting is either located on the ceiling of the weave room or on the ceiling of the room beneath, usually the basement. If the shafting is overhead with a multitude of hangers to drip oil, there is a constant fight to keep down seconds caused by oil dropping on a warp or a cut of cloth. Lighting is unsatisfactory due to shadows from belts. Speeds of looms on the same construction vary due to difference in belt tension and conditions, with a consequent loss in production.

Looms driven from beneath the floor require belt holes for every loom. As the drives operate on very short centers, speed variations are greater than if the looms were driven from the ceiling of the weave room.

The application of individual motors to looms has been one of the most satisfactory ever made to textile machinery. Totally enclosed motors with waste-packed bearings having tapered shafts on which are mounted oil tempered steel pinions that drive to cast iron gears on the looms make an installation that insures constant speed with a maximum production and a minimum amount of maintenance expense.

## • Cloth room

Cloth from the looms is taken to the cloth room where it goes through a brusher which removes loose threads and ends. It then passes over an inspection table where defective pieces are cut out.

From the inspection tables the cloth goes to a folder, which arranges each cut in folds of about one yard. The folded cloth is then placed in a baling press and baled ready for shipment to a finishing plant.

One or two motors usually drive all the machinery in the cloth room through line shafting and belting.

While the air in all departments of a cotton mill is not as full of lint as is found in a spinning room, it is also desirable wherever possible to install motors that are either self-cleaning or that can be cleaned easily.

The development of the multiple V-belt drive and of the self-cleaning and enclosed winding types of motors have had a great deal to do with the acceptance, by practically everyone, of individual drives for spinning and twisting.

Engineering developments have contributed notably to improvement of operating conditions in the various delicate processes involved in cotton textile manufacture. This has resulted in a more uniform product, greater ease of manufacture, and improved working conditions.

• • •

# Photograph Titles

**Cover 1**

Three-Winding Transformers: HV 20,000 kva, 132,000 volts; LV 26,667 kva, 34,500 volts; TV 20,000 kva, 13,200 volts with Forced Air Cooling. *Pastall Photograph.*

**Page 4**

Vertical Wound Rotor Motors Direct Coupled to Centrifugal Pumps. Installed in a Sewage Treatment Plant, 1930. *Pohlman Photograph.*

**Page 10**

Sixty Thousand gpm Circulating Pumps and 53,700 sq ft Single Pass Surface Condenser. *Pohlman Photograph.*

**Page 14**

Magnet Frames and Brush Yokes for a 6000 kw, 600 volt d-c Motor Generator Set. *Pohlman Photograph.*

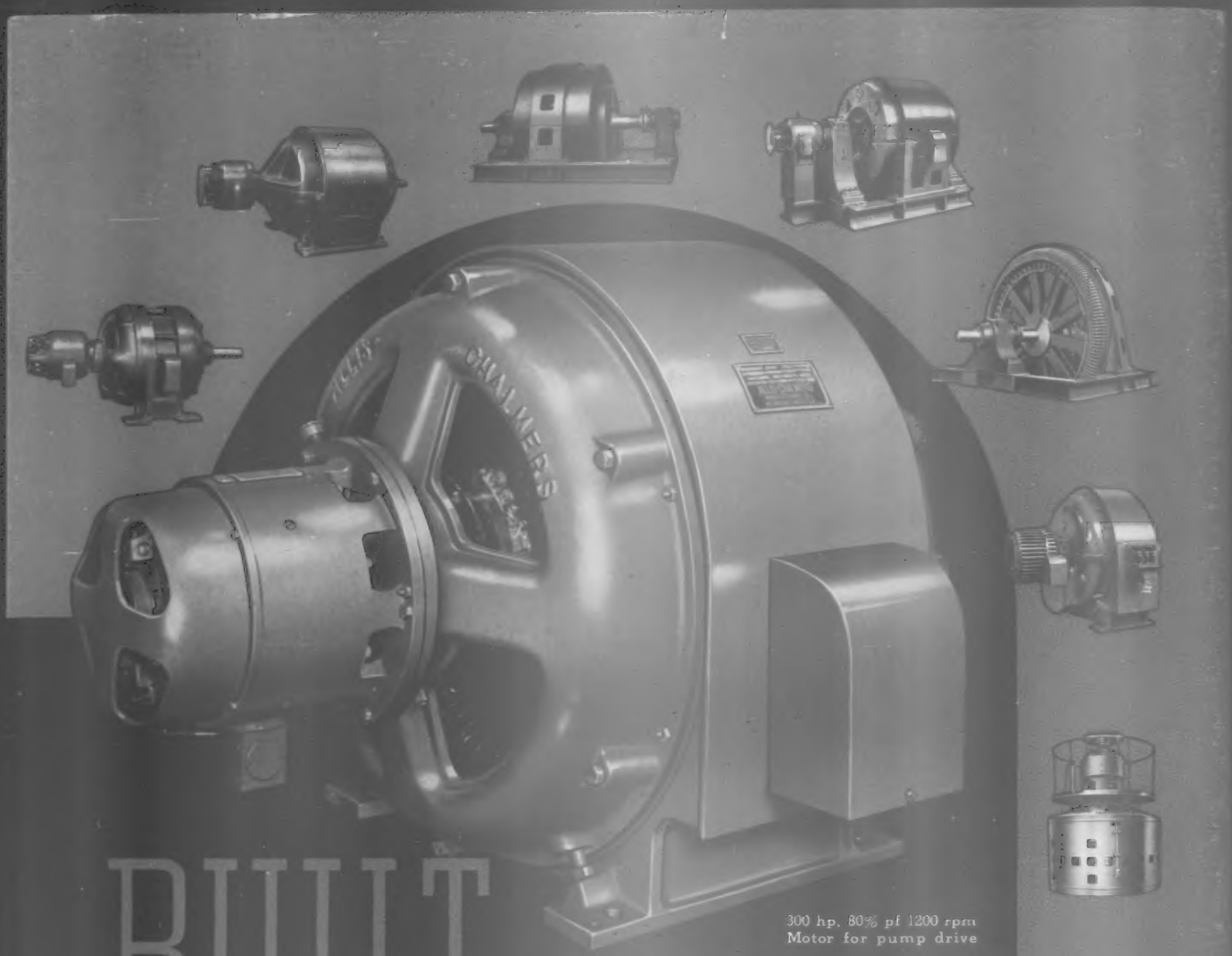
**Pages 20 and 21**

Turbo-Blower Driven by Steam Turbine in Sewage Treatment Plant. Rating: 50,000 cu ft per min, ten lb gauge pressure, 3885 rpm, 2450 hp. *Pohlman Photograph.*

**Page 25**

Internal Cooling Coil, 5000 amp, 600v Mercury Arc Power Rectifier.

"WE NEVER HAVE TO
REPLENISH NITROGEN
IN THESE ALLIS-
CHALMERS INERT
GAS TRANSFORMERS"




300 hp, 80% pf 1200 rpm
Motor for pump drive

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B6

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